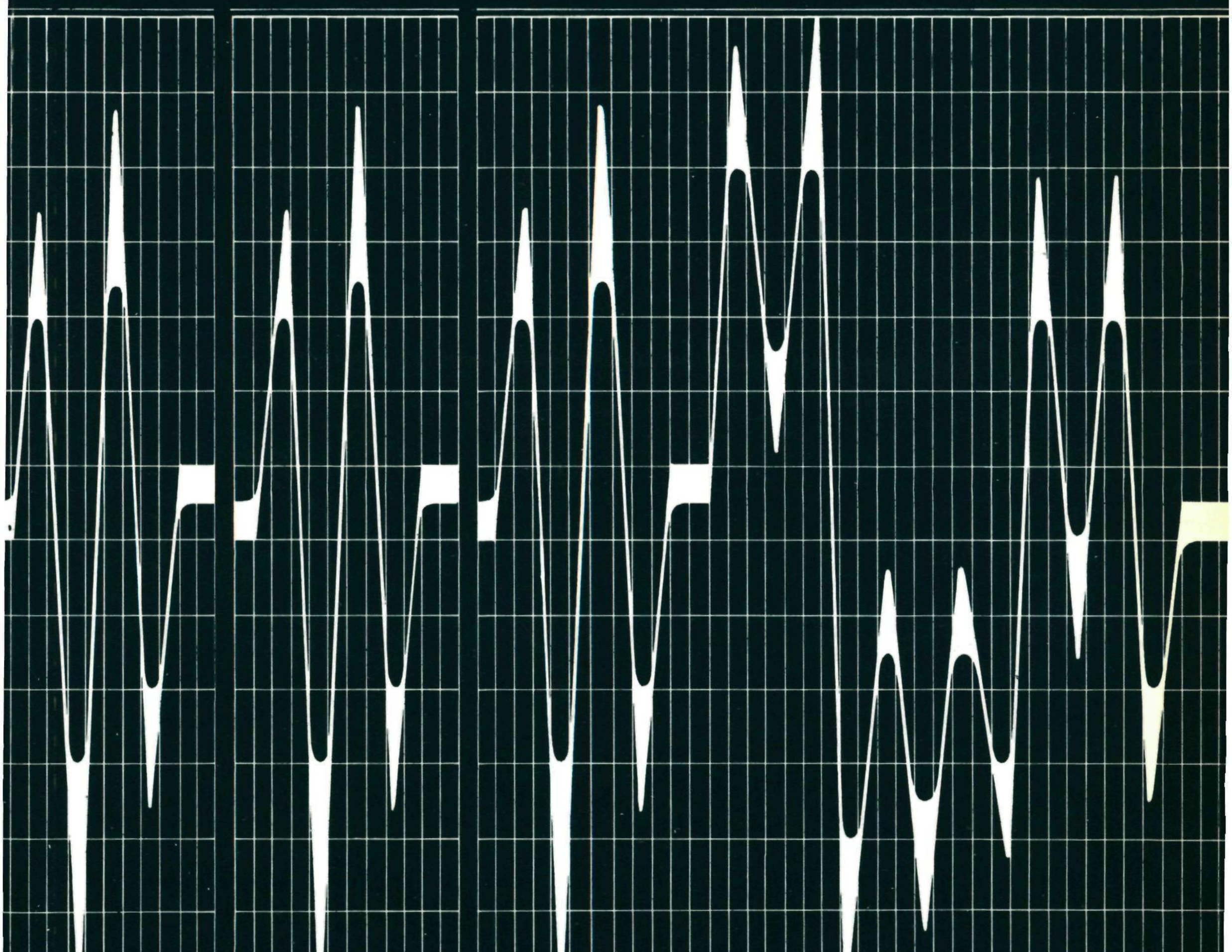
STUTTERING

studies in speech motor behavior



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HERMAN FRANCISCUS MARIE PETERS

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	Prof. Dr. P. van den Broek
Co-referenten:	Dr. W. Hulstijn
	Dr. L. Boves

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CONTENTS

INTRODUCTION

Stuttering is a disorder in the fluency of speech, which manifests itself in inadequate actions of the motor systems involved in speaking, viz. respiration, phonation and articulatory movements. Despite the fact that it has probably received more attention than any other speech disorder, stuttering is still one of the most mysterious speech disorders many aspects of which are still not fully understood.

In recent years a clearer insight has been gained into the nature of the disorder and the factors which possibly stimulate the development of stuttering, such as heredity, linguistic skills, speech behavior and parental attitudes. Clearer insight has also been gained into the factors which might maintain stuttering, such as the influence of environmental and personality factors. However, we are still in the dark as to the actual cause or causes of stuttering.

On the basis of percentages found in the literature pertaining to the number of stutterers in other countries (see Van Riper, 1982), it is estimated that there are about 100.000 stutterers - children and adults - in the Netherlands at the present time. About 25% experience stuttering as a problem for which professional help is required. Contrary to earlier views (e.g. Johnson's Interaction Hypothesis), it is now generally accepted that stuttering is a universal problem which occurs in nearly all races and cultures (Van Riper, op. cit.). The problem has been known for a very long time: stuttering was described on clay tablets in Mesopotamia and shown in hieroglyphs in Egypt, while in ancient Greece stuttering or phthongophobia was already distinguished from other speech disorders.

From the time speech pathology developed into a discipline at the beginning of this century, stuttering has been predominantly approached as an emotional problem. Although initially the general view was that stuttering should be considered a neurosis (i.e. a symptom of underlying emotional disturbances), later, under the influence of psychological learning theories, more attention was paid to stress and emotions directly related to speech which might elicit or cause stuttering.

Recently, in the approach to stuttering there has been a gradual shift towards speech motor aspects of the disorder (Starkweather, in press; Chapters 1 and 4 of this thesis). This is apparent from both the increasing number of descriptions in which stuttering is primarily interpreted as a speech motor disorder and from the strong growth of experimental research into the physiological aspects of speech in stutterers. This trend is also perceptible in clinical practice. It is striking, for instance, that in the treatment of stuttering the systematic build-up of fluent speech is receiving more attention now than in the period prior to 1980. Thus, in the course of the 1970s a number of therapy programs was developed specifically designed for the build-up of fluent speech (Fluency Shaping Therapies), while at the same time, in the so-called broad-spectrum therapies, the systematic changes of speech behavior appear to have been receiving more and more attention.

This thesis is a collection of experimental studies in which the trend to the approach of stuttering sketched above is reflected. In the first part (Part A) the relationship between anxiety and stuttering is the subject of investigation, while in the second part (Part B) various aspects of speech motor behavior are described.

Research into the relationship between anxiety and stuttering is introduced in Chapter 1, where the place and function of anxiety or stress in the different approaches to the stuttering problem are described. This chapter also contains an overview of earlier research into the relationship between stuttering and anxiety. It ends with a description of the questions which were the starting point of the research described in Chapters 2 and 3. According to a number of theories, stuttering is elicited by stress which develops prior to the actual speech situation. If that is the case, one might expect that stutterers show an increased anxiety level in the period directly preceding speech. This assumption is the key issue in the study described in Chapter 2.

It is unclear whether the severity of stuttering is directly related to the anxiety level. In Chapter 3 the data obtained from the study described in Chapter 2 have therefore been analysed further for various levels of severity of stuttering.

The speech motor studies which are the subject of Part B are introduced in Chapter 4. In this chapter, firstly the motor and physiological processes are described as well as the levels on which it can be measured. This is followed by an overview of recent research into various aspects of speech motor behavior in stutterers and primarily a description of the most important theories in which stuttering is mainly regarded as a disorder of speech motor behavior.

From earlier physiological research into speech it can be concluded that especially the onset of speech is difficult for stutterers and it is particularly during the onset of phonation that all kinds of problems occur. The way in which the speech onset is realized by stutterers and the question which processes play a part here are the subject of the experiments described in Chapter 5 up to and including Chapter 8.

The abruptness of voice onset is an important parameter with regard to voice and phonation quality. Stutterers often show laryngeal muscle tension manifesting itself in an abrupt voice onset. Many stutter therapies therefore include exercises to teach the stutterer how s/he can influence the manner of voice onset. However, objective and reliable methods for measuring the abruptness of the voice onset are not available. Chapter 5 contains a description of a study of the reliability of trained speech scientists' judgements of the abruptness of voice onset. Subsequently the relationship between the auditory judgement of the listener and various acoustic measures is investigated. This is followed by a description of a simple instrumental technique for the objective measurement of the abruptness of the voice onset.

The production of fluent speech requires a very precise coordination of movements of the respiratory, phonatory and articulatory organs. It is often assumed that the failure to coordinate the expiratory actions in the correct way with a global adjustment of the laryngeal musculature in preparation for phonation is one of the principal causes of disruption of the fluent onset of speech. Systematic research into the coordination between expiration and adjustment of the laryngeal musculature in preparation for phonation is still lacking at present. An important parameter here is the way in which subglottal pressure is built up prior to the onset of speech.

Chapter 6 gives an account of how the process of subglottal pressure build-up takes place, and a system is proposed for classifying normal and abnormal patterns. The extent to which the patterns found in the subglottal pressure build-up of perceptually fluent speech utterances of stutterers differed from those found in the speech of nonstutterers is examined. A description is also given of the extent to which frequently used strategies to influence phonation and articulation in fluency shaping programs (i.e. speaking with a gentle voice onset and with reduced articulatory effort) influence the patterns of subglottal pressure build-up.

The interaction between expiration, i.e. the subglottal pressure build-up, phonation and articulation is the subject matter of Chapter 7. Apart from the types of pressure build-up described in Chapter 6, vocal cord activity, as represented in electroglottographic records (EGG), and the speech signal are analysed to this end. In order to obtain a description of voice onset, a classification system for the analysis of EGGs is proposed, whereby the abrupt or gentle voice onset as well as the occurrence of irregularities in the EGG in terms of amplitude envelope and period duration can be characterized in the first phase of the voice onset. It is then investigated whether stutterers differ from nonstutterers with regard to the onset of phonation in their perceptually fluent speech utterances, and how this is influenced by the way in which subglottal pressure is built up.

A totally different approach to research into the problems encountered by stutterers with respect to the onset of speech movements is the analysis of the time intervals necessary for the various parts of a movement. It is well-known (cf. Adams, 1984) that stutterers are slower in initiating speech production then nonstutterers. However, it is not clear which processes are responsible for this. The delay may be the result of stutterers needing more time to prepare (in technical terms "programming") the many motor actions of speech, or of more specific difficulties in the actual speech physiological processes prior to speech (termed "initiation" in Chapter 8). The question whether the longer speech-reaction times in stutterers are the result of programming problems or of disturbances in motor initiation is the subject of investigation in Chapter 8.

References

See references Chapter 1

PART A

STUDIES IN STUTTERING AND ANXIETY

CHAPTER 1

STUTTERING AND ANXIETY

1.1. OPINIONS WITH RESPECT TO THE RELATIONSHIP OF STUTTERING AND ANXIETY

It is a widely accepted fact that behavior patterns which require a high level of neuromuscular coordination may suffer from the influence of fear producing stimulus conditions (Martens, 1971; Spielberger, 1971). The production of speech requires a very precise coordination of a large number of respiratory, phonatory and articulatory manoeuvres. In clinical practice it appears as if nearly every stutterer complains that under the influence of anxiety or emotion the disruption in fluent speech production is bound to worsen. Thus it is not surprising that often stuttering is explained as the disruptive effect of negative emotional stimuli on normally fluent speech (Sheehan, 1958; Bloodstein, 1975; Brutten & Shoemaker, 1967).

Regardless of their etiological or methodological persuasion many authors have accepted abnormal amounts and different types of speech related anxiety as an important feature in the syndrome of stuttering. Mostly these descriptions or explanations of stuttering are based on clinical experience with the disorder and they are heavily determined by the professional training of the author. In general these explanations are more or less holistic descriptions of the disorder which, perhaps with the exception of the learning theoretical explanations, inevitably imply that they are difficult to access for experimental research. With respect to the interpretation of speech-related anxiety, theorists in stuttering can roughly be divided into three categories: Firstly, those who explain stuttering from a general factor of anxiety as an antecedent to stuttering behavior and therefore, state that in the therapy of stuttering anxiety problems must be the central aspect. Secondly, those who accept the existence of anxiety as a contributing factor in the production of stuttering and therefore, feel that speech-related anxiety must be dealt with specifically and directly. Thirdly, those who consider anxiety as a secondary factor which is a direct consequence of stuttering behavior, but feel that direct behavioral methods will generate sufficient fluency to result in adequate communicative confidence. Representatives of each position will be discussed in more detail in the next paragraphs.

1.1.1 ANXIETY AS AN ANTECEDENT TO STUTTERING

Historically speech-related anxiety has been considered as an essential, causative element in the development of confirmed stuttering. From the beginning of a more scientific approach to stuttering, which started around 1925 when formal education in speech pathology developed in Europe and in the U.S.A., anxiety formed a dominant theme in theories of stuttering, and a large number of theories explaining stuttering from a general or causative factor of anxiety were developed.

Stuttering as a neurosis. During the period of 1925 until at about 1960 stuttering was often considered as an emotional problem and frequently described as a type of neurosis. In Europe Gutzmann (1924) already described stuttering as a "spira vitiosa" in which speech anxiety is developed by a conscious experience of disfluency. Each new experience was said to increase stutterers' inhibition in the speech situation which induces stuttering. Trömmer (1929) suggested that the inhibition in speech situations evokes anxiety which leads the stutterer to a higher amount of inhibition. Seeman (1959) developed the concept that strong affective and emotional experiences in speech situations might disturb the functioning of the striopallidar system which results in a hyperkinesia (clonic spasm) and hypertonia (tonic spasm).

More recently Fernau Horn (1969) elaborated the ideas of Gutzman from a more psycho-analytic point of view. She described stuttering as the result of a vicious inhibition circle. The recollection of earlier experiences in fluency failure leads to a negative anticipation of coming speech situations. This increase in arousal results in inhibition in the respiratory functions, followed by inhibitional processes in phonation and the initiation of speech.

Especially in the U.S.A. the neurotic origin of stuttering had a wide acceptance during the early thirties and the following decades and many divergent opinions within this perspective were developed. The emotional upheaval of anxiety which was considered as the core of stuttering could be more or less unrelated to the stimuli which trigger it. The symptoms of a neurosis, viz. stuttering, were frequently considered as defenses against the distress of the unexplainable and inappropriate anxiety.

From a psycho-analytic view a variety of attempts have been made to describe stuttering behavior as a neurotic symptom rooted in unconscious needs (Coriat, 1931; Fenichel, 1945; Barbara, 1954; Glauber, 1958). Although these views differed somewhat in their emphasis, in general they start from the idea that stuttering must be seen as symptomatic of conflicts which have been resolved by fixation at the anal or oral levels. In the case of anal fixation the act of stuttering may be considered as an attempt to satisfy anal erotic needs. The function of the anal sphincter is said to be symbollically displaced upward and while stuttering the person actually is sucking to satisfy the infantile libido (Fernichel, 1945). In the case of oral fixation stuttering is said to result from a conflict between the "id" and "superego", since speech not only enables the oral pleasure seaking (sucking) and aggression (biting) but it also serves as basic mechanism for being able to live in a world with others (Glauber, 1958). In such approaches stuttering is seen as satisfying a number of conflicting needs simultaneously.

The view that stuttering results from repressed needs is mainly supported by case studies and clinical observations of psycho-analysts. Evidence from experimental research corroborating this view is, however, extremely scarce. From a literature review of Sheehan (1970) it must be concluded that stutterers do not appear to be more neurotic than nonstutterers.

Stuttering as learned behavior. A new wave of explanations of stuttering emphasized the role of anxiety as an antecedent starts in the beginning of the fifties, originating from learning theory.

One of the first attempts was offered by Wischner (1952) with his proposal that stuttering should be viewed as a 'learned anxiety response system'. Wischner's theory utilized Hullian concepts of drive-reduction to account for the maintenance of stuttering behaviors, the main drive being that of anxiety. He argued that anxiety was integral to stuttering in two possible ways. The first was that the anxiety response is learned, but that stuttering is an unlearned response to the state anxiety produced by the speech act. The second was that both anxiety and stuttering are learned or interlocked responses which reinforce anxiety reduction. By either explanation the act of stuttering was claimed to produce a decrease in the anxiety drive which results in stuttering becoming an instrumentally conditioned response. Wischner also regarded stuttering as a behavior which might permit the direct investigation of the anxiety gradient, viz. the changes in behavior related to the strength of the anxiety drive. Two forms of anxiety were thought to be expressed by stuttering: a general situational anxiety, as evidenced by the effect of different audience sizes on stuttering and specific word anxiety, as manifested in the adaptation and expectancy effect.

During the 1950's two influential theories departing from the idea that stuttering is essentially a learned fear response were developed by Sheehan (1958, 1970, 1975) and Bloodstein (1958, 1975, 1984).

In general the Approach-Avoidance-Conflict-Theory of Sheehan was based on a drive reduction model. The starting point was Miller's (1944) proposition that when a drive to approach and a drive to avoid are in conflict, they result in oscillating behavior. Sheehan viewed stuttering as an oscillation between the desire to communicate (approach drive) and the desire to avoid stuttering conditions (avoidance drive). When the approach and avoidance drive are equally strong, the speakers will move part away to the goal and then stop or oscillate. According to Sheehan this oscillatory behavior results from approach-avoidance at word, situational, feeling, relationship and self-role levels. The occurence of the stutter reduces the fear presumed to underlie the avoidance drive, thereby reducing the avoidance drive and allowing the approach motivational system to dominate, which allows the stutterer to go on. In fact, anxiety and fear associated with speaking and stuttering appear to play three different roles in Sheehan's theory. First, fear is the force behind the avoidance drive which is in conflict with the need to communicate. Second, fear reduction associated with the occurence of the block occasions the termination of the block. And, third, the fear reduction reinforces the instrumental escape and avoidance behaviors that, in part comprise stuttering behavior.

A related theory has been offered by Bloodstein who claims that stuttering may be seen as an anticipatory struggle reaction. In his "Anticipatory Struggle Hypothesis" the stutterer is thought to be constantly anxious about his stuttering. The anticipation of possible difficulties in fluent speech induces anxiety. This fear leads to the production of tensions and fragmentations in speech that, in essence, form stuttering. The heighthened anxiety about speech is considered to be mainly responsible for stuttering.

Although in the approaches of Sheehan and Bloodstein learned behavior plays an important role, it cannot be considered as a strict learning theoretical explanation. Such an approach which has been particularly influential has been presented in Brutten and Shoemakers's two-factor theory (Brutten & Shoemaker, 1967). Brutten and Shoemaker attribute stuttering to classical conditioned negative emotion, viz. anxiety. In normal speech the stimulus field in which speech behavior is elicited usually is associated with either positive or neutral emotion. Occasional fluency failures result from cognitive and/or motoric disorganisation due to various organically determined stress factors. The establishment of the relationship between "specific situational stimuli and negative emotion in essence defines the onset of stuttering" (Brutten & Shoemaker, 1967, p. 33). The particular pattern of speech disruption, viz. repetitions and prolongations (= first factor), is not a learned characteristic but instead represents an automatic emotional response that induces the behavioral/motor disruption. The emotional responses (and associated motor disruption) become associated with specific external stimuli via classical conditioning. The result of repeated conditioning experiences is a speaker who has learned to fear talking, dysfluency and/or specific speech situations. This, in turn, results in a wide range of instrumentally acquired adjustive responses (= second factor), designed to avoid or to escape from the feared speech situations, words and dysfluencies. Contrary to the theories of Wischner and Sheehan in this theory the stuttering moment is not considered as an independent event but as one that is closely linked to classically conditioned autonomic responses. Another distinction is that there is an important shift in the definition of stuttering in that, according to Brutten and Shoemaker, it is not based on its form or frequency, but on the existence of specific stimulus circumstances and negative emotion. In this sense, however, stuttering is limited to a subpopulation of dysfluent speakers. If a dysfluent speaker fails to show evidence of negative emotion, as for instance evidenced by state-anxiety measures, he will not be regarded as a stutterer despite any similarities between his dysfluencies and stuttering.

1.1.2 ANXIETY AS A CONTRIBUTING FACTOR IN STUTTERING

A rather large group of theorists and clinicians have considered anxiety to be a significant but not necessarily a central or causative factor in stuttering. Representatives of such a point of view are among others Gregory (1979, 1986), Gronhovd and Zenner (1982), Janssen (1979), Stournaras (1979) and Van Riper (1973, 1982).

Van Riper (1973) suggested a multicausative etiological basis for stuttering and considered several kinds of speech related anxieties as prominent maintaining and complicating factors. Among these were fear of social penalty, fear of loosing listener's attention and fear of trying to talk and not being able to say anything. According to Van Riper the possibility of success in the management of fully developed stuttering will depend upon the therapist's ability to desensitize the stutterer to his stuttering and to its contributing stimuli.

During the last ten years a number of multicausal models of stuttering inspired by Van Riper have been presented by theorists and clinicians (Gregory, 1979; Gronhovd & Zenner, 1982; Janssen 1979). Although there are subtle differences in various aspects, in general these models have described stuttering as a disorder in which three main behavioral categories or components play a role. These categories concern (1) the disruption in fluent speech production, i.e. the behavioral component (2) the anxieties which are related to speaking, i.e. the emotional component and (3) the self-concept or attitude of the stutterer to himself and his problem, i.e. the cognitive component. These components are not necessarily present in the same way and to the same extent in all stutterers. For instance a severe disturbance in speech fluency can be accompanied by minor anxiety symptoms or negative attitudes; while on the other hand high levels of speech anxiety and/or negative attitudes can be present with very little stuttering behavior.

In the behavioral component of stuttered speech normally a distinction is made between primary behaviors (repetitions, prolongations and broken words) and secondary behaviors (instrumentally learned escape and avoidance responses).

According to Spielberger (1966) the emotional component is comprised of state anxiety and trait anxiety. Speech-related anxiety (state anxiety) is commonly accepted as a frequent concomitant of the syndrome of stuttering. However, its specific role and degree of involvement is explained in different ways. Mostly speech related anxiety is seen as transitory and varying in intensity from moment to moment as a function of the speech situation in which the individual finds himself and refers to the actual autonomic reaction to the specific situation. Examples of speech-related anxieties are sound, word and situational fears. A general chronic anxiety state (trait anxiety), which may be considered as a personality trait that determines the degree to which the stutterer reacts to stressful communicative situations with more specific speech-related anxiety, however, seems to play a less important role (Kraaimaat 1980).

The cognitive component refers to the self-concept of the stutterer in relationship to his speech problem and to his beliefs and knowledge. The stutterer's beliefs and knowledge are judged to be an important clinical factor. In particular these beliefs and knowledge concern the stutterer's own ideas about stuttering in general, his ideas about his own stuttering, his personality, listeners' reactions to his speech, his ideas about how normal speech should sound, and his evaluation of how much dysfluency may be acceptable.

1.1.3 ANXIETY AS A CONSEQUENCE OF STUTTERING

During the last fifteen years there is a strong increase in the approach to stuttering from a speech motor perspective. From clinical practice (Ryan, 1974, 1979; Webster, 1974, 1979; Perkins, 1974 and Starkweather, 1987), from a more theoretical point of view and from experimental research (a.o. Adams, 1974; Wingate, 1976; Zimmermann, 1980; Kent, 1984) stuttering is primarily described as a motor disorder. Contrary to the authors mentioned in the two preceding sections these authors, implicitly or explicitly, accept anxiety only as a secondary factor which is a direct consequence of stuttering behavior.

These authors base their views on the general notion that speech fluency depends on a correct timing and prompt smooth initiation and maintenance of air flow and vocal fold vibration. This can only result from a harmonious integration of aerodynamic, phonatory and articulatory functions. The problem of stuttering is considered primarily as a physiological deficit in one of the speech motor subsystems or in the timing and coordination between these subsystems. Speech-related anxiety is not seen as a central or causative feature but only a secondary response to the presence of stuttered speech.

These motor approaches to stuttering will be described in more detail in the third section of Chapter 4. Within the framework of this section only those approaches should be mentioned that make the role of anxiety more explicit.

Ryan (1974) and Perkins (1974) came up with the idea that no data support the hypothesis that anxiety could be causative in stuttering, but that the speech problem could lead to attitude and anxiety problems. Besides this, Perkins also felt that reduced fear of stuttering may be an important factor in maintaining newly established fluency.

Webster (1979), explicitly, denies the potential role of anxiety as a fundamental causal factor in stuttering. Based on his experiences with the Precision Fluency Shaping Program he stated that after achieving control over fluency-generating targets the stutterer normally speaks fluently in spite of fears, anxiety and life stress. With the initiation of fluency shaping activities stuttering-associated accessory behaviors diminished. The fact that stuttering associated behaviors reliably disappear with the beginning of fluency shaping activities suggests that they are cued by specific stimulus events within the speech process. Therefore, Webster indicated that in clinical practice supplemental desensitization methods are not needed as a component of fluency training.

1.1.4 POINTS OF DISCUSSION

First of all it must be stressed that this section does not pretend to give a comprehensive overview of the literature on stuttering. It was not even the aim to cover all authors who have touched upon the relationship between stuttering and anxiety. The overview has been restricted to those authors who have chosen a more or less clear position. Our attempt to categorize these authors suffers from all shortcomings germane to any classification: not everybody fits into the scheme equally easily. Starkweather (1987) for example recognizes the importance of speech motor problems that may lead to anxiety, but without disclaiming anxiety as an important triggering factor in the development of stuttering.

There is one shortcoming of our category system that deserves some special attention. The way in which the approaches of the stuttering problem are categorized do not reflect the fact that stuttering does not start as a full-fledged disorder that has a stable, static relation to anxiety. In reality stuttering develops and during that development the relation between anxiety and the disorder may change significantly. For instance, it is quite conceivable that stuttering starts as a motoric problem, that this motor problem gives rise to social anxiety which in turn the problem worthes and can trigger and aggrevate the condition of stuttering. It should be mentioned, though, that the static flavor of the category system reflects the neglect of the developmental aspects of stuttering in a considerable part of the literature.

Our review of the literature on the relation between stuttering and anxiety bears out a clear historical trend. While the older authors describe stuttering as a result of a general emotional disturbance or neurosis, the central causative role of anxiety is then operationalized in the form of models drawing on learning theory. Later on learning theoretical approaches abandon anxiety as the exclusive causative factor for explaining stuttering behavior and develop towards the multicausal models that have dominated the field during the seventies. It is not before the turn of the decade that approaches viewing stuttering as a speech motor problem that may cause anxiety gain enough momentum to compete with the multicausal models.

From a clinical point of view the older idea that stuttering is a neurosis that can be succesfully treated by means of psychotherapy has been completely superseded by therapies based on the multicausal approach. Perhaps the most appealing characteristic of this approach is that it allows for the idiosyncrasies of individual stutterers and the circumstances they live in. Because it recognizes a multitude of different aspects that may all play some role the treatment may involve widely diverging excercises even including speech motor training. Thus it is only natural that the term "broad spectrum therapy" has been coined for this approach. Gregory (1979) and Guitar & Peters (1980) amphasize the contrast between the broad spectrum therapies and what they call "Fluency Shaping Therapies" that originate from the opinion that stuttering is essentially a speech motor problem. Presently, however, the edge of this contrast is being taken off, if only because speech motor training is gaining increasing attention in broad spectrum therapies.

1.2 RESEARCH ON THE RELATIONSHIP BETWEEN STUTTERING AND ANXIETY

The theoretical positions mentioned in the preceding sections illustrate the tremendous divergence of opinion among experienced professionals regarding anxiety's specific role and degree of involvement in the nature and management of stuttering. In this section experimental research into the relationship between stuttering and anxiety will be discussed. As could be expected most of this research originated from learning theory models in stuttering. Unfortunately, the results are often contradictory. In this section a discussion of these various studies can be conveniently dealt with under five headings: (1) the relationship between stuttering severity and anxiety, (2) the differences between stutterers and nonstutterers, (3) the effect of anxiety reduction in therapy, (4) the effect of adaptation and (5) the effect of speech tasks.

Frequency of stuttering and anxiety. A first way to investigate the relation between anxiety and stuttering is to examine the relationships between frequency of stuttering and anxiety symptoms. The measurement of anxiety by means of physiological responses such as galvanic skin response (GSR) or heart rate (HR) does not always result in establishing statistically significant correlations between the frequency of stuttering and physiologically detectable anxiety symptoms (Gray and Karmen, 1967; Janssen and Kraaimaat, 1977; Janssen and Kraaimaat, 1980). Of special interest is the study of Gray and Karmen. They investigated the relationship between the frequency of stuttering and physiological arousal as measured by palmar sweat indices (P.S.I.) in mild, moderate and severe stutterers during repeated reading of the same text. They showed a curvilinear relationship in which the moderate stutterers showed significantly higher P.S.I.-scores than the low and high frequency subgroups of stutterers. In the study of Janssen and Kraaimaat the relationship between the frequency of different types of stuttering behavior and anxiety was studied. During a text reading task heart rate, skin conductance level and skin conductance responses were measured in 48 young stutterers (13-16 years). Janssen and Kraaimaat did not succeed in showing a general relationship between stuttering severity and arousal level. However, by looking at different types of speech disfluency, they showed a relationship between anxiety measures and at least one specific pattern of disfluency, viz, fast repetitions.

Comparison of stutterers with nonstutterers. A second type of investigation involves a comparison between stutterers and normal speakers. Results of this type of studies are very contradictory. Gray and Karmen (1967), Gray and Williams (1969) and Janssen and Kraaimaat (1980) found no difference in physiological activity between stutterers and normal speakers before or during a speech task. Brunner and Franck (1975) and Ickes and Pierce (1973), however, report distinctly higher autonomic responses in stutterers during speech.

Brunner and Frank showed a significantly higher increase in heart rate and heart rate fluctuations in stutterers during reading and spontaneous speech in an experiment with 9 stutterers and 7 control subjects. Ickes and Pierce measured vasoconstriction by means of finger plethysmography during a 30 second interval preceding and following reading of single words. Stutterers displayed a significant decrease of blood volume as they approached words on which they stuttered and a significant increase of blood volume after a stutter. On the approach of fluent words stutterers did not differ significantly from the pattern of response of the control subjects. The reduction in state anxiety after a stutter was also identified by Dabul and Perkins (1973) who showed a sharp decrease in systolic blood pressure after a stuttering condition. Both studies indicate that correlates of state anxiety may increase during very brief intervals preceding disfluent utterances and then decrease following a stutter.

The effect of therapeutically manipulated anxiety on stuttering. A third, and perhaps the most interesting approach toward gaining insight into the significance of anxiety in stuttering appeared in studies that have assessed the effect of therapeutically manipulated anxiety on stuttering, or contrarily, the effect of manipulating stuttering on anxiety. Therapy programs aimed largely at reducing anxiety have yielded some evidence of reduced stuttering, together with diminishing subjective anxiety and/or autonomic responses (Gray and England, 1969, 1972; Adams, 1972; Janssen, 1973; Janssen and Damsté, 1976; M. Webster, 1976; Spehr, 1977). Adams (1972), however, is the only researcher to have succeeded in discovering any direct correlation between anxiety reduction and frequency of stuttering using reciprocal inhibition procedures in the treatment of stuttering. In a study by Gray and England (1969) on the reduction of state anxiety after reciprocal inhibition there was no correspondence between stuttering frequency and anxiety beyond a marginal and coincidental one. Janssen and Damsté (1976) also failed to find any relationship using desensitization techniques. Therapeutic procedures directed towards enhancing fluency by means of negative reinforcement or masking noise sometimes result in increasing physiological activity. Adams and Moore (1972) showed a very significant reduction in stuttering frequency under a masking condition; however, they could not detect any changes in palmar sweat indices under different conditions. Also Reed and Lingwall (1976, 1980) showed that during response-contingent experimental treatment procedure with an auditory masking the mean GSR response was virtually unaffected by changes in stuttering. These data at least suggest that there is no etiological relationship between the frequency of stuttering and emotional responding. Negative emotionality and stuttering seem to be relatively independent response classes.

The effect of adaptation. A fourth method deals with the effect of adaptation. Repeated performance of the same speaking task results in a decrease in the frequency of stuttering in most stutterers. Studies into the effect of adaptation on arousal measures yield contradictory results. In the assessment of stutterers' PSI-indices during repeated reading of a text Gray and Karmen (1967) showed that a decrease in frequency of stuttering coincides with a reduction in physiological responses. Kraaimaat (1980) also pointed out that during repeated reading of a text besides a decrease in frequency of stuttering there was a significant decrease in the level in two of three indices of autonomic reactivity. Yet, in other studies no direct relationship between changes in anxiety level as demonstrated by PSI-scores and changes in the frequency of stuttering could be shown (Gray and Brutten, 1965; Gray and England, 1972). Potential decreases in the level of arousal are very inconsistent and cannot explain the effect of reduction in stuttering frequency.

The effect of speech task. Finally there are studies dealing with the effect of speech tasks. Speech situations seem to evoke an increase in physiological responses relative to the level occurring during rest periods before and after the task as shown by Brunner and Franck (1975) and Kraaimaat (1980). However, there are indications that this is also the case in normal speakers (Kraaimaat, 1980). Gray and Williams (1969) and Janssen (1973) have given evidence of differences arising under various speech conditions. In the Gray and Williams study free associations to words show higher levels of arousal than the pronunciation of isolated words. In Janssen study telephone calls show a higher level than reading and spontaneous speech. However, surprisingly enough, non-speech control tasks do not seem to have been employed in either of these investigations.

1.3 CONCLUSIONS

The overall impression of the findings from the studies reviewed above is that at this moment there seems to be little evidence for a direct etiological relationship between stuttering and anxiety; but in a number of cases a functional relationship may exist. However, nearly every stutterer reports speech related anxiety and complains that under the influence of anxiety disfluency in speech may increase; also clinicians tend to judge stutterers compared to nonstutterers among others as more nervous, tense, sensitive, anxious, fearful and insecure than the fluent speakers (Turnbaugh, Guitar & Hoffmann, 1979). Although the majority of the reported studies failed to demonstrate a clear relationship between anxiety and stuttering, the following points must be taken into consideration:

1. All the experiments reviewed before are studies in which anxiety is operationalized almost exclusively in terms of arousal measures. However, it is now generally accepted that anxiety may comprise different components and that at least a behavioral component, a physiological component and a cognitive component should be distinguished (Mandler, 1976; Strongman, 1978). Although these three components are usually integrated, they need not necessarily go together. The association between somatic features of anxiety and the actual experience of anxiety seems to be an asynchronous one. So, physiological evidence of anxiety is not necessarily an evidence that the subject actually experiences anxiety and vica versa (Schwartz, 1978). However, at the moment it is hardly possible to assess rapid changes in behavior as the result of stress inducing conditions in verbal communication in an objective way. With respect to the cognitive component this certainly may be possible with semantic differential techniques. However, these techniques are not always reliable because the scaling judgments have to be carried out after task execution and it is quite unclear which factors will influence the judgment at that moment.

2. Practically all studies that were reviewed show great differences with respect to the methodological aspects. Data are based on one or more different speech tasks like the reading of text or spontanous speech elicited in different ways and mostly no control tasks are used. There are many procedural differences in the way experiments are carried out

and mostly only one single physiological response measure is used. Therefore, it is very precarious to compare the results of different experiments with each other, or to make generalisations from acquired data.

3. Perhaps stuttering comprises different types of disfluency, each of which probably could stand in a different relationship to anxiety as indicated by Brutten (1975) and Janssen and Kraaimaat (1980).

4. Studies on the relationship between anxiety and stuttering are only concerned with speech situations. However, the question remains whether increased anxiety during stuttering is a characteristic specific for speech situations, or whether it may also be demonstrated in other social situations or tasks which seem to be analogous with speech situations.

5. The physiological component of anxiety includes a number of responses differing in the extent as well as in the direction of their reactions (Greenfield and Sternbach, 1972; Pribram and McGuiness, 1975). It is a well-known fact that under any given condition of the organism, mobilizing for a response or attending to vegetative functions some organs will become active, others will increase their action, and other systems will decrease this action. Furthermore, it is documented that there is a considerable variability of individual physiological response patterns evoked by the same stressor. So for instance, although many subjects show concordant heart rate and skin conductance increases when alerted for oncoming stress, there remains a substantial number of subjects who show marked activity in only one system. In most of the research, however, only a single variable has been recorded. Simultaneous recording of different response systems (c.q. skin conductance level, heart rate, pulse volume) does not solve this problem, because there is no agreement on the way in which the individual measures should be processed and combined in order to obtain a valid assessment of the arousal level (Lang, 1971).

6. In most studies the physiological parameters have been measured during the performance of a speech task. The advantage of observing physiological variables lies in the production of a continuous record. One of the disadvantages, however, may be that there is no clear relationship between anxiety and physiological activity during the task. Moreover, the increase in physiological arousal may largely be the result of the mental effort demanded by the task. Beside this, any increase in motor activity and/or possible irregularities in respiration may also

lead to changes in physiological activity. Therefore, the measurement of emotional tension can best be performed during the period of anticipation prior to the execution of the task, when the subject knows what he has to perform and is quietly waiting to begin. Inclusion of an anticipation period also makes it possible to ascertain whether anxiety is already present during this anticipation period and, therefore, is an antecedent to stuttering, or whether it is truly concomitant with stuttering behavior.

1.4 INTRODUCTION TO THE EXPERIMENTS

The purpose of the studies described in chapters two and three was firstly to investigate possible differences between stutterers and non-stutterers during the anticipation period preceding speech tasks. According to the two-factor theory of Brutten and Shoemaker (1967) an increase of arousal may be expected during this period in stutterers but not in nonstutterers.

A second question addressed was whether the presence of physiological activity during stuttering is restricted to speech situations, or whether it also extends to other tasks in which the subject is disrupted in his motor behavior or has to realize socially desired behavior. To this end a motor task and an intelligence task were introduced as controls.

A third aspect of the inquiry concerned the adaptation effect. The above-mentioned studies reveal contradictory results with respect to a decrease in physiological activity following repeated exposure to the same task. It was assumed that this decrease will also be manifest during the anticipation period, while there is no need that this will be the case during the task period.

Additionally in chapter three the data from the experiment described in chapter two were analysed with respect to the relationship between the severity of stuttering and physiologically detectable anxiety symptoms. To this end the group of stuttering subjects from chapter two's study was split up into three different subgroups, viz. mild, moderate and severe stutterers.

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CHAPTER 2

STUTTERING AND ANXIETY
The difference between stutterers and nonstutterers in verbal apprehension and physiologic arousal during the anticipation of speech and non-speech tasks

Herman F.M. Peters

and

Wouter Hulstijn

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SUMMARY

To test if stressful anticipation of speech situations is a factor in eliciting stuttering behavior, the difference between 24 stutterers and 24 nonstutterers in verbal apprehension and physiologic activity was studied before and during speech tasks (reading and conversation), and nonspeech tasks (motor and intelligence task).

Results indicate that the difference between stutterers and nonstutterers mainly were restricted to anxiety ratings assessed after each task. Heart rate, vasomotor responses, and electrodermal activity recorded before and during speech tasks were higher compared with the physiologic activity before and during nonspeech tasks but, unexpectedly, this was also the case for nonstutterers. It is concluded that stuttering is not elicited by anxiety.

2.1 INTRODUCTION

Anxiety in speech situations plays an important role in many theories on the origin of stuttering (Brutten and Shoemaker, 1967; Bloodstein, 1969, 1975; Sheehan, 1975) and in therapies for helping stutterers (Ingham and Andrews, 1971, 1973; Adams, 1972, Gray and England, 1972; Brutten, 1975). This becomes especially evident in the theory of Brutten and Shoemaker, who postulate that anxiety in speech situations is the result of classical conditioning. Anticipation of speech situations evokes or intensifies anxiety, resulting in desintegration of speech. Although not all theories agree in attributing such a causal role to anxiety, the majority start from the viewpoint that elimination of anxiety should be an important target in therapy.

The important role assigned to speech anxiety probably is due to the clinical experience that nearly every stutterer complains of speech-related anxiety. In contrast to this, the results obtained from more systematic research on the relation between anxiety and stuttering failed to demonstrate a clear relationship (Gray and Karmen, 1967; Gray and Williams, 1969; Gray and England, 1969; Adams, 1972; Ickes and Pierce, 1973; Ingham and Andrews, 1973; Brunner and Frank, 1975; Janssen and Damsté, 1976; Janssen and Kraaimaat, 1980; Kraaimaat, 1980; Reed and Lingwal, 1976, 1980).

Anxiety may be said to be built up from different components. There is a behavioral component (the avoidance of speech situations), a verbal component (the speech-related anxiety often reported by stutterers) and a physiologic component (a change in physiologic arousal involving reactions of the autonomic nervous system). Although these three components are usually integrated, they need not necessarily go together (Mandler, 1976; Strongman, 1978). The physiologic component includes a number of variables differing in the extent, as well as in the direction, of their reactions (Greenfield and Sternbach, 1972; Pribram and McGuinness, 1975). In most of the earlier research, only one variable has been recorded. Additionally, in most studies, the physiologic parameters have been measured during the performance of a task (usually speech). The advantage of observing physiologic variables lies in the production of a continuous record, but the disadvantage is that there is no clear relationship between anxiety and physiologic activity during the task. Moreover, the increase in physiologic arousal may largely be the result of the mental effort demanded by the task. Beside this, any increase in motor activity and/or possible irregularities in respiration also may lead to changes in physiologic activity. Therefore, the measurement of emotional tension can best be performed during a short period of anticipation prior to testing, when the subject knows what the task to be performed is and is quietly waiting to begin. The inclusion of an anticipation period also makes it possible to ascertain if anxiety is present before initiation of speech, or if it is truly concomittant with stuttering.

The primary purpose of this study was to investigate possible differences between stutterers and nonstutterers during the anticipation period preceding speech tasks. According to the two-factor theory of Brutten and Shoemaker (1967), an increase of arousal may be expected during this period.

A second question addressed was whether the presence of physiologic activity during stuttering is restricted to speech situations only, or if it also extends to other tasks. A motor task and an intelligence task, therefore, were introduced as controls.

A third aspect of the inquiry concerned the adaptation effect. Earlier studies reveal contradictory results with respect to a decrease in physiologic activity following repeated exposure to the same task (Gray and Brutten, 1965; Gray and Karmen, 1967; Gray and England, 1972; Kraaimaat, 1980). It was assumed that this decrease will also be manifest during the anticipation period, while there is no need that this will be the case during the task period.

2.2 METHODS

Subjects

Subjects consisted of 24 stutterers (20 male, 4 female) and 24 nonstutterers (19 male, 5 female); ages ranged from 18 to 37 years. For stutterers, the audiorecording of the spontaneous speech task was judged by a practicing speech pathologist. Dysfluencies were defined as any sound, syllable, word, or phrase repetition, interjection, prolongation, and block. The percentage of dysfluencies ranged between 10% and 77%. The control subjects were recruited among students and hospital employees who had no history of speech disorders.

Design and Procedures

All subjects performed the same tasks. The speech tasks consisted of reading a text and holding a conversation; the control tasks were mirror writing and an intelligence task. The order of these tasks was counterbalanced. Before performing the tasks, the subjects had an adaptation period of 5 min and two repetitions of a simple writing task, in order to become acquainted with the standard procedure for every task. This standard procedure started with an instruction, followed by a rest period of 30 sec (the anticipation period), and then a task period, usually lasting 2 min. The subjects then rated their subjective anxiety, on a 5-points scale, during the just preceding task, followed by a 30-sec recovery period.

The subject was seated in a small room in front of the experimenter (an experienced speech therapist) and faced a TV camera. The registration apparatus was housed in an adjacent room and was controlled by a second experimenter who could follow the subject on a TV monitor.

Tasks

The speech tasks were taken form a standard assessment procedure. First, the subject had to read a 200-word text silently, marking the words at which stuttering was expected. Then the subject read the same text aloud. This reading aloud was repeated five times with the same text. Generally, the nonstutterers read the text within 2 min. Before, or for one-half of the subjects after, this reading task the subject had a 2-min conversation with the experimenter on a topic chosen by the subject. This conversation was introduced to assess stuttering in spontaneous speech.

In the mirror writing task, the subjects were asked to copy simple words, as fast and correctly as possible, while their stylus was visible only through a mirror. The intelligence task was composed of items from the Raven intelligence test displayed on slides. In the first intelligence task, which lasted 30 sec, only three easy items were presented. In the second task, the subject was instructed that the items would be much more difficult. In fact, the difficulty of the items was gradually increased and the task was stopped when the solution time exceeded 20 sec for three successive items. For this task, only the last 2 min were analyzed. The solution time was measured by an electronic clock, triggered by the pulse for the next slide and stopped by the subject as soon as the correct answer was reached.

Anxiety Measures

The level of anxiety or emotional tension was estimated in three ways. The verbal component was registered by asking for a subjective rating of anxiety experienced following the completion of each task. The physiologic component was continuously monitored by means of recording skin conductance, spontaneous fluctuation in skin conductance, heart rate, and digital blood pulse volume in a finger throughout the experiment. In addition, general trait anxiety was evaluated by questionnaires.

Physiologic Variables. Skin conductance level and spontaneous fluctuations in skin conductance were measured by a Conductron 330 (Enting). This apparatus operated with an AC voltage of 0.775 V and 5.25 Hz. The lead-electrodes had a contact area of 6.4 cm^2 and were fixed with an agar-agar, 0.05 M KCl, conductive paste to the third phalanx of the index and third finger. The skin conductance level was logarithmically written on one channel of a Honeywell Visicorder 1858 with a sensitivity of 0.04 log µmho/cm. Spontaneous fluctuations were recorded on a second channel with a time constant of 4 sec and an accuracy of 0.05 µmho/1.5 cm. Only responses greater than 0.05 µmho were counted as spontanous fluctuations.

Digital pulse volume was measured by a finger-photoplethysmograph affixed to the extreme phalanx of the middle finger of the nondominant hand. This signal was amplified by a Honeywell accudata 133 and written on the Honeywell Visicorder.

Heart rate was counted from the pulse volume registration.

The four physiologic variables were scored from the paper recordings every 10 sec and averaged over 30-sec periods. The initial resting level was calculated over the last 30 sec of the adaptation period; the final resting level was determined during the final resting period after the recovery period of the last task.

Trait Anxiety Questionnaires. Trait anxiety was measured by the neuroticism scale (N-scale) and the neurotic somatic complaints scale (NS-scale) of the "Amsterdamse Biografische Vragenlijst" (Amsterdam Biographical Questionnaire; Wilde, 1963). Failure anxiety was measured by the debilitating anxiety scale (DA-scale) and facilitating anxiety scale (FA-scale) of the "Prestatie Motivatie Test" (Achievement Motivation Test; Hermans, 1967).

Data Analysis

Analysis of variance followed a repeated measurement design, with the difference between both groups as the between subject variable, and the tasks or anticipation periods as within subject variables. A significance level of $p = 0.05$ was maintained throughout this study.

2.3 RESULTS

The dependent variables are split up into three categories. First the subjective anxiety data are presented, since they give the most simple picture, then the results on the four physiologic variables will be dealt with extensively, and finally there will be a short summary of the outcomes of the personality tests.

Subjective Anxiety

Immediately after each task, the subjects rated their subjective anxiety on a 5-point scale ranging from 1 (calm) to 5 (very tense). The mean scale values for stutterers and nonstutterers are presented in Figure 1. The results are completely in line with the predictions.
Stutterers are more tense than nonstutterers ($F(1,46) = 12.53$, $p < 0.01$). Note that this difference is most marked after the tasks involving speech. The interaction between groups and tasks is highly significant ($F(12,552) = 5.19$, $p < 0.001$).

Physiologic Responses

The average values during anticipation, task, and recovery periods for skin conductance level (SCL), spontaneous fluctuations in skin conductance (SF), pulse volume (PV), and heart rate (HR), for both groups are presented in Figures 2, 3, 4, and 5.

It should be noted that the sequence in which the speech task and the two control tasks were presented, was balanced across subjects. The two writing tasks were always first. Within the block of speech tasks, one-half of the subjects had the conversation first.

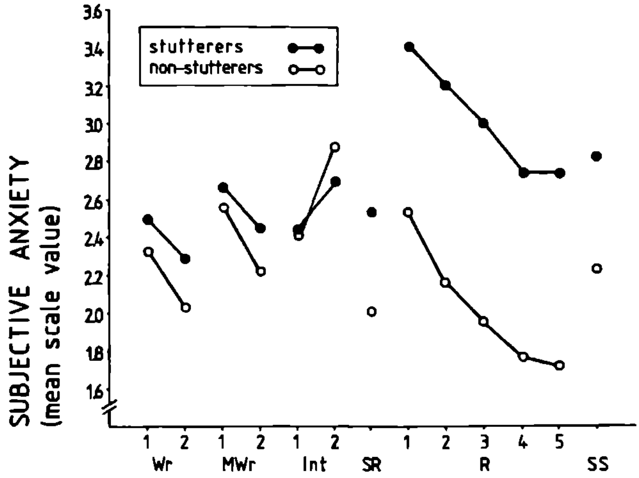

Figure 1: Mean subjective anxiety for stutterers and non-stutterers rated directly after two or more repetitions of writing (W), mirror-writing (MWr), intelligence task (Int), silent reading (SR), reading (R) and spontaneous speech (SS).

Group differences. The difference between stutterers and nonstutterers will be given for three types of data, i.e., resting values, anticipation data, and task data.

The resting values, taken as the mean of the first and final resting period, do not differ significant between stutterers and nonstutterers (SCL:$F(1,46) = 0.60$, $p = 0.55$; SF:$F(1,46) = 0.18$, $p = 0.68$; PV:$F(1,46) = 2.57$, $p = 0.11$; HR:$F(1,46) = 2.11$, $p = 0.15$). For SCL and HR, however, these differences are rather large although not significant) (SCL: stutterers = 1.47, nonstutterers = 1.51, difference = -0.04 log µmho; HR: stutterers = 78.3, nonstutterers = 73.5, difference = 4.8 BPM), compared with the size of the task effects (Figures 2 and 5). Therefore, the SCL and HR values have been changed by their usual correction, i.e., by using the main resting level as a baseline value, which is subtracted from values obtained during the experiment. The usual correction for pulse volume, expressing each amplitude as a percentage of the resting level, did not reduce the apparent difference between both groups in Figure 3 and, therefore, has been omitted. In all analyses in this and the following sections, both data (corrected as well as unchanged) did produce comparable results. Only the F values of the data presented in the figures will be given.

The second and third test for group differences can be made by analyzing the difference between both groups on all 13 anticipation periods

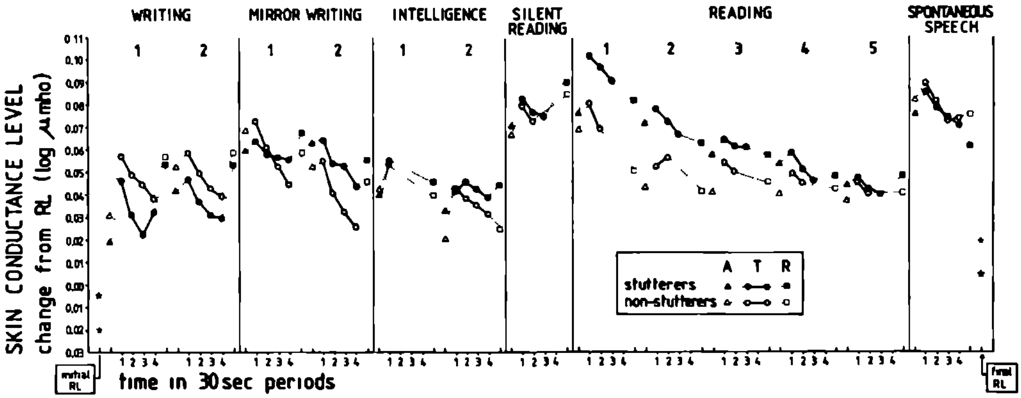

Figure 2: Mean Skin Conductance Level for stutterers and non-stutterers during the 30 sec anticipation periods (A), during the four 30 sec task periods (T) and during the 30 sec recovery periods (R) of the indicated tasks.

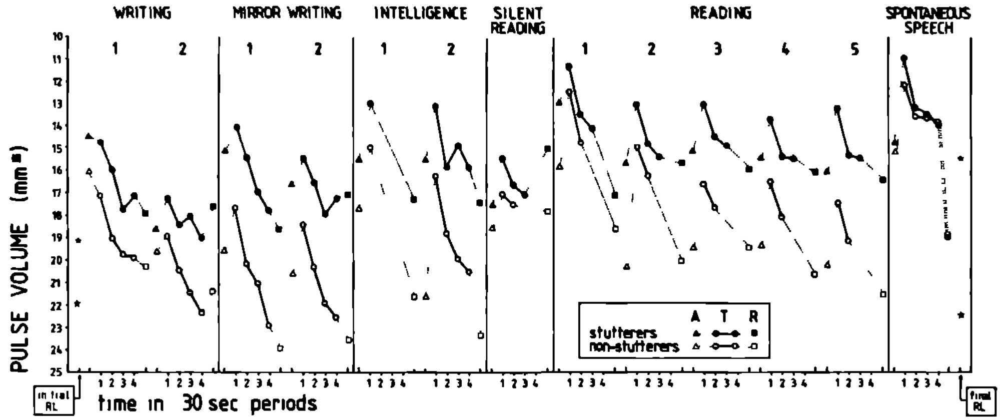

Figure 3: Mean Pulse Volume for stutterers and non-stutterers during the 30 sec anticipation periods (A), during the four 30 sec task periods (T) and during the 30 sec recovery periods (R) of the indicated tasks.

and on all 13 tasks. Inspection of Figures 2 through 5 suggests that, generally, the mean values of both groups are very close together. This suggestion is corroborated by the analyses of variance. Neither the mean anticipation period values (SCL:$F(1,46) = 0.19$, $p = 0.73$; SF:$F(1,46) = 0.002$, $p = 0.96$; PV:$F(1,46) = 1.40$, $p = 0.24$; HR:$F(1,46) = 1.29$, $p = 0.26$) nor the mean task-period values differ significantly (SCL:F(1,46 = 0.06, $p = 0.80$; SF:$F(1,46) = 0.37$, $p = 0.55$; PV:$F(1,46) = 1.13$, $p = 0.29$;

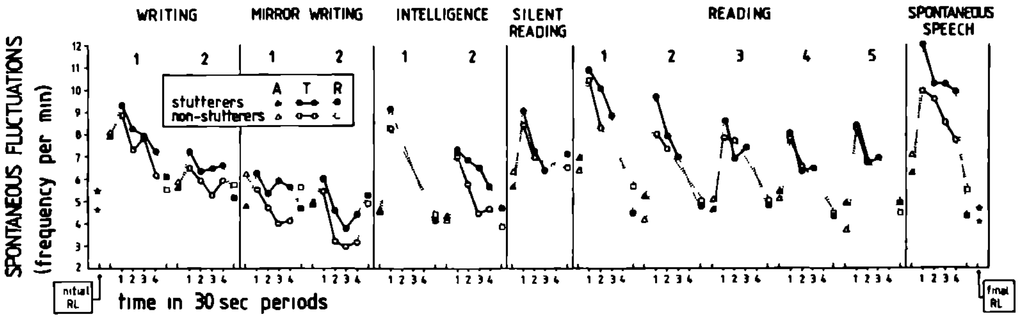

Figure 4: Mean Frequency of Spontaneous Fluctuations per minute for stutterers and non-stutterers during the 30 sec anticipation periods (A), during the four 30 sec task periods (T) and during the 30 sec recovery periods (R) of the indicated tasks.

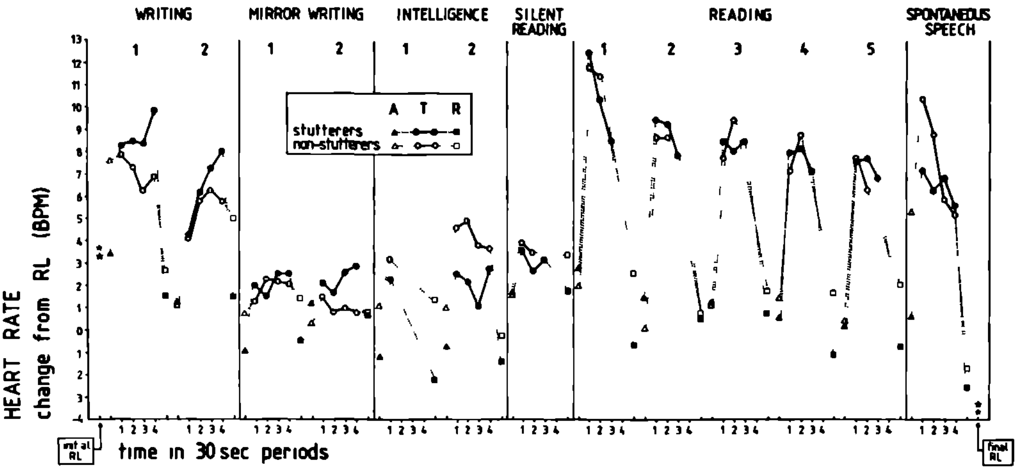

Figure 5: Mean Heart Rate per minute for stutterers and non-stutterers during the 30 sec anticipation periods (A), during the four 30 sec task periods (T) and during the 30 sec recovery periods (R) of the indicated tasks.

HR:$F(1,46) = 0.01$, $p = 0.91$). The latter analyses were made on the data of the first 30-sec periods of the tasks, since the first intelligence task lasted only 30 sec.

The pulse volume data in Figure 4 seem to form an exception, since all data from stutterers, except one, are situated above those of the non-stutterers. However, this impression is only apparent, since these data are correlated, not independent. For example, the mean correlation coefficient between all possible pairs of the 13 anticipation period values is r = 0.763 for PV, which is rather high compared with r = 0.467 for SCL, r = 0.651 for SF, and r = 0.320 for HR. Furthermore, the variation between individual subjects is very high. For the mean anticipation-period values, the standard deviation in pulse volume is 8.4 mm for stutterers and 10.1 mm for nonstutterers. The comparable data for SCL are 0.044 and 0.042, 3.99 and 4.68 for SF, and 2.92 and 2.93 for HR.

Anticipation and Task Data. In summary, the overall differences between stutterers and nonstutterers are not significant. However, it might be reasonably expected that, simular to the subjective anxiety data, a difference between stutterers and nonstutterers will manifest only before or during the speech tasks, and not on the control tasks.The interactions between groups and tasks, therefore, are the most interesting outcomes of the analyses of variance. For the 13 anticipation periods, these interactions are not significant (SCL:$F(12,552) = 0.95$, $p = 0.50$; SF:$F(12,552) = 0.73$, $p = 0.73$; PV:$F(12,552) = 1.32$, $p = 0.20$; HR:$F(12,552) = 2.54$, $p < 0.01$)).

The significant interaction for the heart rate data is an exception. Figure 5, however shows that, although stutterers have higher anticipation values than nonstutterers on some tasks, this is not consistently the case for all speech tasks. The high heart rate value of the nonstutterers in the anticipation period of the spontaneous speech task is contrary to all expectations.

The anticipation data as well as the responses during the tasks, analysed on the first 30 sec of each task, did not produce significant interactions between groups and tasks (SCL:$F(12,522) = 0.97$, $p = 0.52$; SF:$F(12,522) = 0.37$, $p = 0.97$; PV:$F(12,522) = 0.58$, $p = 0.86$; HR: $F(12,552) = 0.90$, $p = 0.55$).

These negative results cannot be explained by a general insensibility of the physiologic responses. On the contrary, the main task effects are all highly significant for the anticipation data (SCL:$F(12,522) = 7.14$, $p < 0.001$; SF:$F(12,552) = 5.98$, $p < 0.001$; PV:$F(12,552) = 3.97$, $p < 0.001$; HR:$F(12,552) = 6.76$, $p < 0.001$), as well as for the task data (SCL: $F(12,552) = 6.95$, $p < 0.001$; SF:$F(12,552) = 11.96$, $p < 0.001$; PV:$F(12,552) = 7.74$, $p < 0.001$; HR:$F(12,552) = 25.06$, $p < 0.001$).

It is quite clear from the Figures 2 through 5 that the highest values are reached before and during the first reading task and the spontaneous speech task. The latter speech tasks were compared with the two control tasks: the first mirror drawing task and the first part of the intelligence task in separate analyses of variances. For each of the four physiologic variables, this results in four comparisons of the anticipation data and four comparisons of the task data. Of the 16 comparisons of the anticipation data, only four were not significant, as in the difference between both speech tasks and the first mirror drawing task for skin conductance level and spontaneous fluctuation. In all of these comparisons, similar to the larger analyses, the difference between tasks was equal for both groups. None of the 16 interactions between groups and tasks turned out to be significant.

Finally, it should be mentioned that, in general, the responses in the anticipation periods are lower than during the first 30 sec of the tasks. These differences are highly significant on all four variables. Moreover, these differences are not the same on each task, as can be seen in the Figures 2 through 5; the interactions between tasks and these differences are highly significant.

Adaptation. In general, repetition of the same reading task leads to a decrement of arousal. The hypothesis was made that this decrement should occur at least in the anticipation periods, since these periods will be more free of artefacts. However, it is clear from the Figures 2 through 5 that the downward curve of the task values is even more marked. Furthermore, inspection of the figures for SCL and PV suggests that the rate of decline over the five reading tasks is not the same for both groups.

Analyses of variance were performed to test these effects, for each of the four variables on the anticipation data, and separately on the task values of the five reading tasks. The task values in these analyses were the average values of the first 60 sec, since that was the minimum time spent by every subject in reading the required number of 200 words. The repetition effect, i.e., the difference between the five repetitions of the task, appear to be highly significant in all eight analyses (Anticipation data: SCL:$F(4,184) = 7.30$, $p < 0.001$; SF:$F(4,184) = 4.94$, $p < 0.005$; PV:$F(4,184) = 7.86$, $p < 0.001$; HR:$F(4,184) = 2.79$, $p < 0.05$; Task data: SCL:$F4(1,84) = 15,80$, $p < 0.001$, SF:$F(4,184) = 11.62$, $p < 0.001$; PV:$F(4,184) = 10.96$, $p < 0.001$; HR:$F(4,184) = 18.19$, $p < 0.001$). Subsequent trend analyses revealed that this task effect can be explained by highly significant linear trends in the four variables during anticipation (SCL:$F(1,184) = 26.78$, $p < 0.001$; SF:$F(1,184) = 10.03$, $p < 0.005$; PV:$F(1,184) = 16.09$, $p < 0.001$; HR:$F(1,184) = 6.82$, $p < 0.01$), as well as during the task (CSL:$F(1,184) = 57.58$, $p < 0.001$; SF:$F(1,184) = 34.21$, $p < 0.001$; PV:$F(1,184) = 39.00$, $p < 0.001$; HR:$F(1,184) = 62.04$, $p < 0.001$). The downward curves of the task values also exhibits a small but significant quadratic trend in all four variables (SCL:$F(1,184) = 4.18$, $p < 0.05$; SF:$F(1,184) = 11.38$, $p < 0.005$; PV:$F(1,184) = 4.15$, $p < 0.05$; HR:$F(1,184) = 6.84$, $p < 0.01$). With the exception of PV, this quadratic trend is not significant for the anticipation data (SCL:$F(1,184) = 0.17$; SF:$F(1,184) = 2.33$; PV:$F(1,184) = 5.63$, $p < 0.025$; HR:$F(1,184) = 0.43$).

To test whether the adaptation of the stutterers differs from that of the nonstutterers a linear trend was calculated for each of the two groups, and these separate trends were compared with the trend of the means of both groups together. In fact, the linear component of the interaction between groups and repetitions was calculated. These interactions themselves are neither significant for the task values nor for the anticipation data. However, in agreement with the impression obtained from the SCL and PV figures, the linear component of the interaction between groups and repetitions is significant for SCL and PV (SCL:FC 1,184) = 4.79, $p < 0.05$; PV:$F(1,184) = 7.51$, $p < 0.01$). This is only the

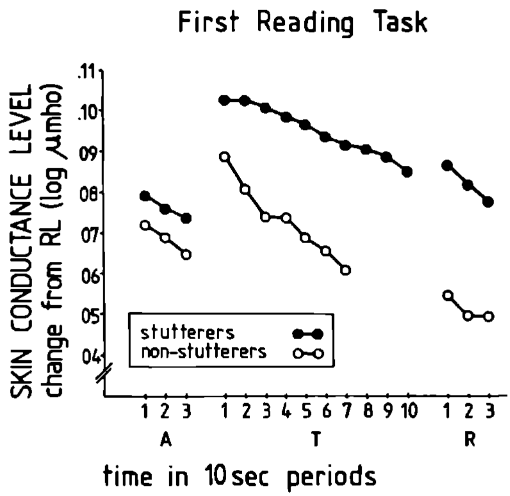

Figure 6: Skin conductance level during the first reading task for stutterers and non-stutterers. Samples were taken every 10 sec in anticipation, task and recovery period.

case for the task values; the corresponding values for the anticipation data are far from significant (SCL:$F(1,184) = 0.33$; PV:$F(1,184) = 0.28$), as well as the linear components of the interactions of HR and SF.

The reading task data for SCL and PV, although both showing a group difference in the rate of adaptation, do not give the same picture. The pulse volume data suggest a more rapid decrement of the nonstutterers, while the SCL data seem to offer the largest difference between both groups in the first reading task. A more detailed examination of the SCL data of the first reading task presents a modifications of this picture. In Figure 6, the averages over succeeding 10-sec periods, before, during, and after the first reading task are given. It is obvious that both groups are still more or less equal in the anticipation period, but diverge after the first 10-sec period of the task. This difference in adaptation during the task is significant. Although the interaction between groups and 10-sec periods is not significant ($F(6,276) = 1.95$, $p = 0.07$), trend analysis produced a significant linear component of this interaction ($F(1,276) = 8.65$, $p < 0.01$).

Table 1.: Mean scores and standard deviations of stutterers and nonstutterers on four subscales measuring trait anxiety

		Stutterers		Nonstutterers	
Method[a]	Scale[b]	M	SD	M	SD
ABV	N	65.4	28.7	59.4	26.3
	NS	59.2	24.1	50.5	27.0
PMT	DA	7.74	2.37	6.45	2.60[c]
	FA	3.41	2.41	6.83	2.46[d]

[a] ABC = Amsterdamse Biografische Vragenlijst; PMT = Prestatie Motivatie Test

[b] N = neuroticism scale; NS = neurotic somatic complaints scale; DA = debilitating anxiety scale; FA = facilitating anxiety scale.

[c] Difference between groups is significant, $p < 0.05$

[d] Difference between groups is significant, $p < 0.01$

Trait Anxiety

Finally, the mean scores of stutterers and nonstutterers on the two personality inventories are given in Table I. There are no significant differences between both groups on the neuroticism scale (N-scale), and the neurotic somatic complaints scale (NS-scale) of the "Amsterdamse Biografische Vragenlijst" ($t(46) = 0.76$ and $t(46) = 1.18$). However, with both failure anxiety scales of the "Prestatie Motivatie Test" significant differences are observed. On the debilitating anxiety scale (DA-scale) stutterers showed significantly higher scores ($t(46) = 1.80$, $p < 0.05$) and, in agreement with this, on the facilitating anxiety scale (FA-scale) the reverse holds true ($t(46) = 4.87$, $p < 0.01$).

2.4 DISCUSSION

The results can be summarized by the statement that stutterers differ from nonstutterers mainly in the verbal components of anxiety. There were only minor differences between both groups in the physiologic responses. The most remarkable result is that not only stutterers but also nonstutterers show more physiologic responses before and during speech tasks than in other tasks. However, stutterers differ from nonstutterers in the rating of their subjective anxiety during the speech tasks. Secondly, there is an indication that, during the reading tasks, stutterers are habituating a little slower than nonstutterers.

The main objective of this study was to test if stutterers differ from nonstutterers, particularly during the anticipation of speech tasks. The only difference between both groups (i.e., the different adaptation rates in SCL and PV) were restricted to the task values and were not significant for the anticipation data.

With respect to the problem of generalization of anxiety, the insertion of control tasks proved to be of great value. The results obtained with the control tasks clearly indicate that there is no generalization of speech anxiety to other tasks. The most remarkable finding is that both stutterers and nonstutterers show a higher physiologic activity to speech tasks. This agrees with the investigation of Knight and Borden (1979) showing that there is an increment of physiologic activity in normal speakers before and during speech performances in which the subject is judged. Moreover, the present study reveals that not only judgment situations but also conversation with other people results in higher levels of tension. Further studies, in which speech situations differing in the nature of stress elicited are chosen, can reveal if there is a more general communicative stress or if anxiety is particularly associated with specific types of speech situations.

The repeated exposure to the same task results in a decrement of arousal for both groups for each of the four variables in the anticipation periods, as well as in the task periods. Contrary to the hypothesis that a decrease in physiologic activity after repeated exposure to the same task will be manifest during the anticipation periods, the difference between stutterers and nonstutterers seems to be most marked in the task period. Although the differences are not the same in the various physiologic response systems, the SCL-scores show the largest differences during the first reading task. The differences in PV-scores become manifest at a later time. During the task periods, nonstutterers show a typical habituation curve (Hulstijn, 1978). Stutterers have a more linear decrement of physiologic activity. Analysis of the SCL-scores of the first reading task demonstrates that during this task stutterers adapt slower than nonstutterers. One can only speculate on its cause. A psychologic explanation may be that during reading, the stutterer is confronted with the handicap and this experience evokes anxiety, while, from a physiologic point of view, in stuttering there is a desintegration of the respiration process, which can easily induce a higher level of physiologic activity.

In this study, stutterers seem to differ from nonstutterers only in the verbal component of anxiety and not in the physiologic component. It could be that physiologic measures are relatively insensitive. On the other hand, there are subtle differences in scores between the various tasks, which are highly significant. Furthermore, in contrast to the high deviation between the mean score of individual subjects, there is a rather good consistency in the scores on the experimental periods within individual subjects. Another possibility may be that, since the physiologic measurements record anxiety as well as activation, activation probably is the main component.

Another difficulty in the interpretation of the results concerns the scaling method in subjective anxiety. Physiologic activity is measured before and during a task; subjective anxiety, however, is scaled after the event, which implies that different experiences are fused. In agreement with this interpretation is the high correlation, found by Janssen and Damsté (1976), between the frequency of stuttering and a self-rating of subjective anxiety. In the present study, however, this correlation is not significant ($r = 0.25$, $n = 24$).

Our study clearly shows that stutterers do not score at a higher level in general trait anxiety scales of a personality inventory, compared with nonstutterers. This agrees with the results of earlier investigations (Sheehan, 1970). Interestingly, the scores on both failure anxiety scales indicate that, in stuttering, a higher level of failure anxiety is present in stressful situations. The stuttering subjects in this study are those who presented themselves for therapy, however, which probably implies that their stuttering was experienced as a real handicap.

By separating the anticipation and the task period, this study was supposed to contribute to the solution of the crucial problem of whether anxiety should be considered an antecedent or a consequence of stuttering. It will be clear that the data do not provide evidence for theories that explain stuttering from a general factor of anxiety, which elicits stuttering behavior (Brutten and Shoemaker, 1967; Bloodstein, 1975; Sheehan, 1975). In stuttering, the anticipation of speech situations does not result in a higher level of physiologic activity. The differences observed between both groups were restricted to the rate of adaptation. This slower adaptation, however, was not antecedent, but subsequent, to stuttering.

In stuttering, speech anxiety obviously seems to be a more restricted response complex. Stutterers' reports of speech-related anxiety must be considered as limited to the cognitive component of anxiety. This can be explained in various ways. According to the covert conditioning model of Mahoney (1974) and the investigations of Schachter (1971) it is possible that stutterers are interpreting normal internal processes, such as a higher level of physiologic activity in speech situations, as the result of their handicap. If this assumption is correct, it presents important consequences to stuttering therapy. Procedures directed at changing cognition and attitudes can be presumed to be more effective than procedures directed at general relaxation. Subjective experience from clinical practice seems to support this conclusion.

CONCLUDING REMARKS

The relationship between anxiety and stuttering is not yet clear. As mentioned before, investigations in which tension or anxiety is manipulated by putting subjects in situations that differ in the nature and amount of stress induced, seem to be a missing link in the research. In addition, most investigations use complex speech tasks, such as reading and spontaneous speech, resulting in a continuous alternation of fluencies and dysfluencies, wherein fluencies may neutralize the effect of dysfluencies. For this reason, research on word level is needed.

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CHAPTER 3

RELATIONSHIP BETWEEN ANXIETY AND STUTTERING SEVERITY

3.1 INTRODUCTION

The results from the experiment described in Chapter 2 indicate that there were only minor differences between stutterers and nonstutterers with respect to the physiological component of anxiety. However, it is well-known that stutterers cannot be considered as a homogeneous group and that there may be large differences between the individual stutterers with respect to stuttering behaviors and the level of anxiety (Bloodstein, 1976; Ingham, 1984; Van Riper, 1982). It is quite possible that the failure to find significant differences in anxiety between stutterers and nonstutterers is due to the large individual differences in the group of stutterers.Significant differences might show up if the overall group of stutterers is split up into a number of more homogeneous subgroups. In this chapter such a division is investigated based on stuttering severity as criterion.

From theories which explain stuttering primarily from a general or causative factor of anxiety (Bloodstein, 1975; Brutten and Shoemaker, 1967; Sheehan, 1975) one should expect that the more serious stutterers display higher levels of physiological activity. Gray and Karmen (1969, however, showed that the subgroup of stutterers with the moderate frequency of fluency failures demonstrated a significantly higher level of physiological anxiety as measured by the palmer sweat index than the low and high dysfluency subgroups, which generated essentially similar anxiety patterns. In a correlational study of Janssen and Kraaimaat (1977), on the other hand, stuttering severity as represented by the total number of dysfluencies in a reading passage was relatively independent of autonomic responses as represented by skin conductance level and heart rate. However, if the result found by Gray and Karmen may be generalized it predicts a curvilinear relationship between stuttering severity and physiological arousal; in such a situation linear correlation measures necessarily turn out to be very low. In fact, straight forward correlation analysis then is no longer an adequate technique for approaching the problem.

The purpose of the present study was to explore the question whether the more severe stutterers display higher levels of physiological anxiety, or whether moderate stutterers show the highest responses as reported by Gray and Karmen. A replication of their study seems to be desirable, if only because it seems to contradict the customary clinical opinion that severe stutterers have higher anxiety drive levels than moderate or mild stutterers. If Gray and Karmen's findings prove to be correct, the ideas underlying much clinical work need some reevaluation.

3.2 METHODS

Tasks, procedure and anxiety measures

The experimental tasks were described in the section on Methods in Chapter 2. For a description of the design and procedure and the anxiety measures which were recorded continuously during the experiment the reader should see Chapter 2 also. The assessment of stuttering severity was based on the first reading task and the spontaneous speech task only.

Measurement of stuttering severity

As described by a number of authors (Bloodstein, 1981; Ingham, 1984; Van Riper, 1982) the measurement of stuttering severity should reflect the frequency of stuttering, speech rate, the duration of moments of stuttering, tension and variability in stuttering. Frequency counts converted to either a percentage of words or a percentage of syllables stutterered are the most frequently used method of assessing stuttering severity. Such measures, however, do not pay attention to other relevant parameters like speech rate, the duration and/or seriousness of moments of stuttering and associated physical concomitants which may be of influence on the overall severity of stuttering. However, there is no agreement on the way in which these parameters should be measured, nor on the way in which the measurements should be combined to an overall measure of stuttering severity. By contrast frequency counts are easy to administer and relatively precise.

For this reason in this study stuttering severity was only determined by frequency counts. Frequency counts of dysfluencies were obtained for each subject during the first reading task and during the conversation task. In order to establish the number of dysfluent words the types of dysfluency behavior described by Janssen and Kraaimaat (1977, 1980) were assessed independently. In this scoring procedure the main types of dysfluency (silent blocks, prolongations, sound and syllable repetitions) are counted along with phrase repetitions, incomplete phrases, sound and words interjection and breathing abnormalities. Audio recorded speech samples were judged by three speech pathologists who were previously trained in scoring these categories; they only started the scoring after they had reached an inter-observer and intra-observer reliability of .90 based on the percentages of agreement. The percentage of stuttered words ranged from 0.4 to 85.2% in the reading task and from 10.1 to 76.6% in spontaneous speech. Owing to the detailed and very precise scoring procedure that was used the mean values of the dysfluency percentages may seem to be relatively high compared with other studies. As frequently seen, the correlation between the dysfluency percentage in both tasks was quite small (Pearson r = .386). In none of the tasks did the location of the stutterers on the continuum of zero to one hundred percent dysfluency suggest a "natural" grouping of the subjects, because the distribution does not show any breaks. Therefore, the total group of stutterers was split up into three subgroups of 8 stutterers each.This division in sub-groups was based on the percentage of dysfluencies in the first reading task. The stuttering percentage of the eight stutterers in the low frequency subgroup ranged from 0.4 to 9%, the next eight stutterers which were assigned to the moderate-frequency subgroup ranged from 12 to 28% and the eight stutterers who had the highest frequency of dysfluency (high frequencies subgroup) ranged from 30-85%.

3.3 RESULTS

Anticipation periods and speech tasks

First the average values during the periods of anticipation prior to the speech tasks as well as during the task periods itself were calculated for each of the subgroups. There were no significant differences between the three stuttering subgroups for spontaneous fluctuations in skin conductance (SF), pulse volume (PV) and heart rate (HR) in the anticipation period nor in the task periods. Only in skin conductance level (SCL) differences between the subgroups could be detected. The mean SCL values for these groups in the anticipation and task period in each of the speech tasks are shown in Figure 1. To make the analyses compatible with the analyses reported in Chapter 2, the task values were averaged over 30-sec periods. In general, the differences between the subgroups observed on the nonverbal tasks (writing, mirror writing and intelli-

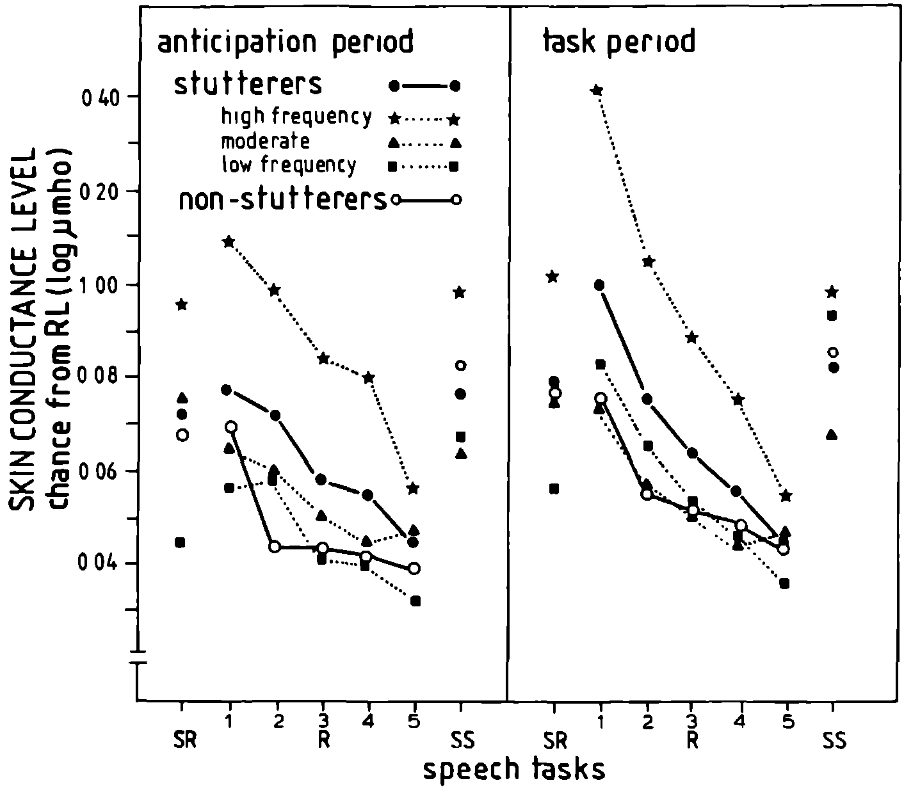

Figure 1: Skin conductance level for stutterers, subgroups of stutterers and *non-stutterers in the different speech tasks - silent reading* (SR), *reading* (R1-5) and spontaneous speech (SS) - during the 30 sec anticipation period and the first 60 sec of the task period.

gence) were smaller than in the speech tasks, although they showed the same overall appearance, i.e. a tendency for the high frequency subgroup to exhibit higher SCL levels than the remaining two subgroups. Therefore, for reasons of clarity they have been omitted from the figures.

Figure 1 suggest higher mean SCL values in the high frequency subgroup of stutterers than for the moderate and low frequency subgroup. The difference between the subgroups averaged over the five reading tasks, however, was not significant ($F(2,21) = 1.32$, $p = .29$). Further, Figure 1 demonstrates that in the SCL measurements the high frequency subgroup of stutterers has a much steeper adaptation over the successive reading tasks than in the moderate and low frequency groups of stutterers. In the first reading task the SCL values for the high frequency group are twice as high as in the moderate and the low frequency subgroups. The interaction between the subgroups and the repetition of the reading tasks, however, is not significant for the anticipation data ($F(8,84) = 1.27$, $p = .27$) but it is significant for the task values ($F(8,84) = 2.70$, $p < .01$).

Intuitivily, the failure to find significant differences between the subgroups in an analysis of variance is not very satisfactory, given the obvious way in which the high frequency subgroups stands out in Figure 1. Therefore, an attempt was made to bring out this difference by means of the more sensitive statistical technique of linear trend analysis. If straight lines are fitted through the data of Figure 1, and the interaction is tested, not on the subgroup means but on these linear trends, of these trends analysis reveales a difference in slope between the subgroups. The linear component of the interaction is significant for the anticipation data ($F(2,84) = 3.75$, $p < .05$) and the task data ($F(2,84) = 10.25$, $p < .01$). These results are somewhat different than those obtained in Chapter 2 for the group of nonstutterers and the complete group of stutterers, where significance was restricted to the task period. Here we see that the low and moderate stuttering subgroups do not differ from the control group, neither in the anticipation nor in the task period, but that the severe stutterers clearly stay apart from the other sutterers and the control group, both in the anticipation and the task period.

Within-task Adaptation

As mentioned already in the discussion of Chapter 2 the only difference between the group of stutterers and nonstutterers was found in the first reading task. As described in section 2.2 a linear trend was calculated for stutterers and nonstutterers and these separate trends were compared with the trend of the means for the combined groups. Recall that there was a significant difference between both groups in adaptation with respect to the task values in repeated reading in SCL and PV measurements.

To check whether the difference in adaptation between stutterers and non-stutterers as shown in Figure 6 of Chapter 2 for the SCL measurement should be attributed to the scores of the subgroup of high frequency stutterers only, the same analysis was carried out on the SCL-responses of each of the three subgroups of stutterers. In Figure 2 the SCL-scores for the high frequency, moderate and low frequency stutterers are shown

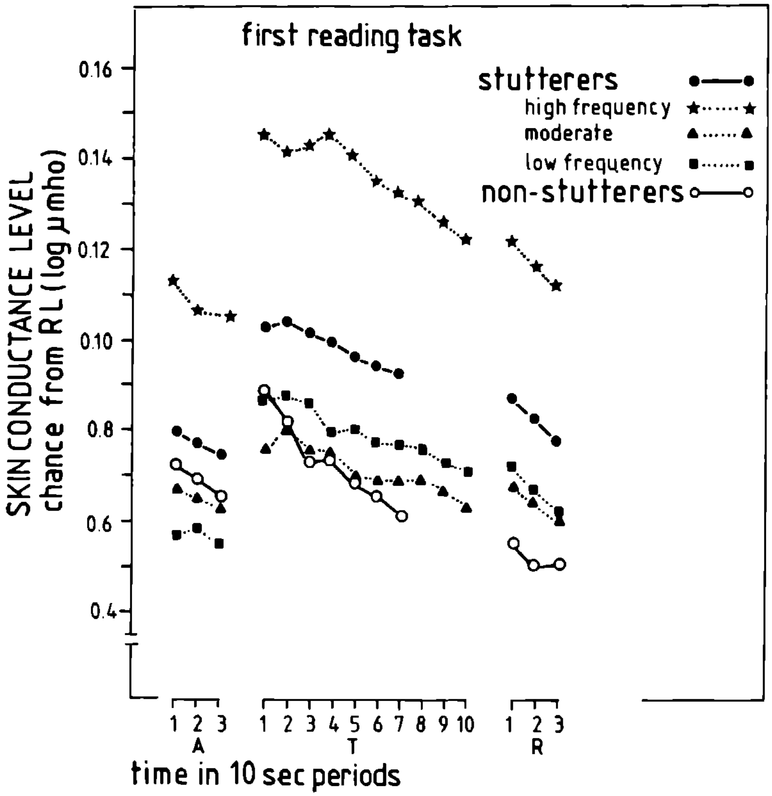

Figure 2: Skin Conductance Level during the first reading task for stutterers, subgroups of stutterers and non-stutterers. Samples were taken every 10 seconds in anticipation, task and recovery periods.

together with the mean scores of all stutterers and the nonstutterers. The responses of high frequency stutterers are all well above the other two groups. However, the group effect in the analysis of variance on the ten-sec values of the three groups is not significant ($F2,21) = 2.75$, $p = 0.09$).

During the task periods nonstutterers showed a stronger decrement of SCL than the stutterers. As shown in Figure 2 all three subgroups reveal the same adaptation rate. The mean linear trend of all the stutterers, calculated on seven 10-sec periods in order to be compatible with nonstutterers' group data, was highly significant ($F(1,126) = 37.77$, $p < .001$). The linear component of the interaction was not significant ($F(2,126) = 0.03$) suggesting a parallel trend for each of the subgroups.

3.4 DISCUSSION

In general there are no large differences in autonomous responses between high frequency, moderate and low frequency subgroup of stutterers. The group effect in the analysis of variance was not significant. The differences were found to be limited to the first reading task during which the high frequency subgroup showed higher SCL values than the moderate and low frequency subgroup in the anticipation period as well as during the task period. The SCL-values of the low and moderate frequency subgroup of stutterers are at the same level as the nonstutterers. The differences between the subgroups in the first reading task, however, are not large and only marginal significant. In looking at the figures one should realize that the Y-axes in Figure 1 and 2 are expanded.

The results from this experiment are quite different from the results obtained by Gray and Karmen (1969). In their study the moderate stutterers showed the highest arousal. In this study more or less the reverse was found since, although the moderate and low frequency subgroup did not differ significantly, the moderate group had task values lying even below those of the low frequency group.

The data from this study alter the results from Chapter 2 somewhat. It appears that the conclusions from Chapter 2 hold for low and moderate frequency group of stutterers. The interesting thing is that the difference between the high frequency subgroup and the low and moderate subgroups seems to appear already during the anticipation period. However, this tendency not only occurred in the speech tasks, but also in the non-verbal tasks.

A number of different explanations can be given. First, some subjects happen to exhibit higher SCL levels than others for biological reasons. These subjects may be overrepresented in the high frequency subgroup of stutterers. Second, it is possible that the high frequency subgroup may be characterized by a higher level of trait anxiety resulting in an overall higher SCL level. Third, it also can be hypothezised that the elicited hig-her SCL level during the anticipation period of the tasks resulted in a higher SCL level during the task itself as a sort of after effect. Finally, it is quite possible that the expectation of a very difficult task may result in a higher level of arousal. It can be assumed that for high frequency stutterers a speech task requires much more effort both mentally and physically, than for the low and moderate subgroup.

Consequently the observation that a higher proportion of stuttering appeared after a higher level of arousal during the anticipation of a task does not lead to the conclusion that stuttering is the consequence of that higher level of arousal. One can just as well suppose that the expectation of a higher frequency of stuttering, which may be quite correct on the basis of former experiences, leads to a higher level of arousal already before the task.

3.5 CONCLUDING REMARKS

Results from the studies described in the Chapters 2 and 3 indicate that in speech tasks as well as in nonspeech tasks there are only minor differences in physiological responses between stutterers and nonstutterers. Only marginally significant differences between subgroups of stutterers could be detected in the sense that the high frequency subgroup of stutterers showed slightly higher SCL levels. In this study the difference between stutterers and nonstutterers seems to be most clear in the self report of anxiety, viz. the rating of anxiety experienced following the completion of a task.

Anxiety, at least state-anxiety in the cases of elicited fear, can be conceived as "a response complex consisting of verbal reports of anxiety and apprehension, physiological arousal involving the sympathetic branch of the autonomic system and behavioral phenomena such as avoidance and performance inefficiency" (Lick and Katkin, 1976, p. 175). The data from this study suggest that probably with the exception of the high frequency stutterers the differences between stutterers and nonstutterers do not manifest themselves in differences in physiological arousal.

The interpretation of the arousal measures is very difficult, except for one aspect: from the failure to find significant differences in physiological activity it may certainly not be concluded that there are no differences in anxiety. For the rest it must be realised that the arousal measurements are extremely "noisy". Autonomic responses may be the result of elicited fear, but they may be as well due to physical and/or mental effort (Mulder, 1980; Sanders, 1983) or disruptions of the respiration process. Presently, it is not clear how to isolate the anxiety component in the physiological signals from the contributions of the remaining factors. The problem is particularly evident in the task conditions, where physical and mental effort are known to contribute to the overall arousal level.

Another limitation of this study may be the fact that the non-arousal measurements, i.e. the self-reports of anxiety, were made after the execution of the task. It is reasonable to assume that subjects will be able to report their experience of fear-eliciting stimuli more accurately after they have just encountered these stimuli than while filling out questionnaires after the completion of the whole experiment. Moreover the accuracy of self-reports is doubtful and so therefore is the validity of the measurement technique. As already discussed in Chapter 2, it may be quite possible that the subjects confused the experience of stuttering severity with the experience of anxiety.

In this experiment no behavioral indications of anxiety were recorded. In measuring speech anxiety it is possible to rate the occurrance of anxiety manifestations in facial expressions and gestures (e.g. trembling hands, speech blocks, throat clearings and so on). In stuttering, however, this measurement may be practically impossible since these verbal and nonverbal behaviors form a characteristic part of the dysfluent speech production process itself.

As mentioned previously in Chapter 2 the relationship between stuttering and anxiety is not yet clear. Presently, there is no experimental evidence for theories which explain stuttering exclusively from a general factor of anxiety. Yet, the clinical observation that stutterers seem to report a fairly consistent relation between anxiety and stuttering severity remains to be explained. However, if stutterers self-reports are analysed in detail, they appear to indicate that in some situations stuttering is more severe than in others and that situation-related tension certainly helps to aggravate stuttering. Thus it seems that a simple explanation that stuttering is caused by anxiety is not even supported by clinical experience.

The finding that the relation between anxiety and stuttering severity is very complex and perhaps even situation dependent makes it extremely difficult to investigate experimentally. First of all, subjects differ widely with respect to sensitivity to fear-inducing conditions. Next, they may differ in the way in which they react to these conditions.

Thirdly, and in the framework of research into stuttering perhaps most importantly, speech related anxiety may develop itself from previous experiences in comparable situations. As a consequence, a situation that is highly fear-inducing for one subject may be quite neutral for another, simply because he has no previous negative experience. To end with, it is not completely clear what the relevant dependent variables are that should be measured under several anxiety manipulating conditions. Thus it appears to be very complicated to design methodologically sound experiments to study the relation between stuttering and anxiety.

Nobody will deny that fear may affect the execution of complex operations, nor that speech production is such a complex operation. But then again, complex operations may be affected in numerous ways. Looking at the present knowledge of speech motor behavior of stutterers, be it in fluent or dysfluent utterances, it appears that very much is still unknown. Yet, regardless of the ultimate underlying cause or causes, stuttering eventually shows up as a disturbance of the normal speech production process. Thus it is only natural that the emphasis appears to shift from the relation between anxiety and the disorder to a more detailed study of the way in which the disorder manifests itself in the most tangible way, viz. in a disturbance of speech motor processes. This approach will be followed in the remaining chapters of this book.

REFERENCES

See references Chapter 2.

PART B

STUDIES IN SPEECH MOTOR BEHAVIOR

CHAPTER 4

SPEECH MOTOR BEHAVIOR IN STUTTERING

4.1 INTRODUCTION

Besides the views described in Chapter 1, in which fear was regarded as the most important factor in stuttering, in former years it was always assumed that stuttering was the result of an organic or physiological defect. Especially in the 1930s to 40s a number of organic explanations for stuttering were developed in which the cause of stuttering was particularly sought in disturbed central brain functions. Thus, at that time Orton (1927) and Travis (1931) developed the so-called "cerebral dominance theory" and later on Weiss (1964) came up with the idea that stuttering was caused by a so called "central language imbalance", which might be the result of striopallidar lesions. It is partly through the lack of support for such notions that in the 1960s and 70s the theoretical explanations described in Chapter 1, section 1.1 superseded the more physiological views of stuttering and greatly influenced the approach to the problem of stuttering.

The application of theoretical explanations for stuttering has led to very plausible descriptions of its development as well as of the emotional and cognitive problems in the individual stutterer. But, the speech-motor aspect of stuttering has hardly received any attention. However, from the research aimed at the emotional aspects of stuttering, as described in 1.2, not enough proof has been established to support the notion that speech-motor disturbances are probably chiefly caused by emotional factors. At the same time it appeared that despite the sometimes very consistent treatment strategies, derived from the learning theoretical explanations, many stutterers continued to stutter, albeit in a more comfortable and relaxed manner. This suggests that speech-motor deficits form a separate phenomenon. As a result, renewed interest arose in the mid 70s for the subject of predisposing constitutional factors in stutterers. This interest gave rise to a flood of research on the various motor and perceptual systems involved in the speech process. This research was stimulated by the improved instrumentation and measurement techniques, due to which differentiated research could take place on respiration, phonation and articulation movements.

This chapter begins with a general description of the speech production process and the levels at which this can be measured (section 4.2). Then an overview is given of the most important results of the speech physiological research in stutterers (section 4.3). Besides this specific research into physiological processes, a number of more general descriptions of stuttering, aimed at an explanation, are brought forward, in which an organic disposition for stuttering forms the basic principle. These notions are discussed in section 4.4. The final section containes an introduction to the specific questions relating to the experiments described in Chapters 5 through 8.

4.2 SPEECH MOTOR PRODUCTION AND ITS MEASUREMENT

Speech production may be considered as one of man's most complex behaviors in which various physical, psychological, linguistic and emotional processes play a role besides numerous physiological processes related to peripheral speech motor production.

The power supply for speech is the air expired from the lungs; in the upper airway the flow is transformed into audible sound. This can be done in three alternative ways: first, by vibrations of the vocal folds resulting in periodic modulation of the air flow which gives rise to periodic acoustic signals (for example in the sounds /a/, /o/, /v/, /m/). Second, by impeding the airstream with the organs of articulation so as to cause turbulence resulting in aperiodic sounds known as noise (for example in the sounds /s/, /h/). The third type of sound source consists of the explosion noise which results from the sudden release of the overpressure build up by temporarily blocking the airway completely, so that the pressure in the upper airways becomes equal to the lung pressure (for example in the sounds /p/, /t/). The three sound sources described here may be combined in several ways. Every single source, however, requires coordinated actions of the respiratory system and one or more structures in the upper airway.

To begin the process of phonation (also called voicing), it is necessary to adjust the vocal folds in such a way that the passing airstream can set them into vibration. This process is described in more detail f.i. by Broad (1973). The conditions necessary to initiate and maintain vocal fold vibrations are: (1) that the pressure below the vocal folds be higher than above (in normal conversational speech approximately 8 cm H_2O) and (2) that the vocal folds themselves be in the proper elastic condition and (3) that the folds are properly adducted. The production of turbulence noise also requires a positive lung pressure in combination with a positioning of the articulators in such way that a properly formed constriction is formed. The production of plosive sounds requires a positive lung pressure in combination with a positioning of the articulators in such a way that the airstream is completely interrupted, followed by a sudden release of the pressure due to a very fast movement of the articulators responsible for the closure.

The sound source produced by vocal fold vibration or by impeding the airflow by articulatory movements must be transformed into recognizable speech sounds. This transformation occurs as a result of changes in the shape of the vocal tract brought about by movements of the articulators: the tongue, jaw, velum, pharynx and lips.

From the descriptions given above it appears that peripheral speech production can be considered as a process in which neuromuscular signals are transformed into movements of the articulators in coordination with the activity of the larynx and the respiratory system; eventually, these actions result in the acoustic waveforms that form the output speech (Baer & Alfonso, 1982). In each of the subsystems involved, namely the respiratory, the phonatory and the articulatory systems, a number of levels should be distinguished at which speech production processes can be measured.

These measurement levels are:

1. **the physiological level.** Parameters at this level are directly related to the muscle activity of respiratory, phonatory and articulatory systems.

2. **the movement level.** At this level initial positioning or posturing movements can be distinguished from the phonatory and articulatory movements proper. Relevant parameters for the initial positioning of structures are: the expiratory force, the condition of the vocal folds and the shape of the vocal tract. The parameters of phonatory movement are: periodicity in successive vibrations, amplitude of vibration, speed of excursion, contact area between vocal folds and so on. The parameters of articulation movements are position, velocity and acceleration of tongue, velum, jaw and lips as individual articulators and their mutual coordination.

3. **the acoustical level.** The nature of the speech sounds generated can be specified with acoustic and psychoacoustic parameters. Examples of

acoustic parameters are fundamental frequency, intensity and spectral characteristics like formants and anti-formants. The psychoacoustic parameters are pitch, loudness, voice quality and so on.

Because speech production is a multiparameter process occurring on a number of levels, measurements in a single domain or at a single level are necessarily incomplete. The acoustic signal depends in a complex way on the positions and movements of the various articulators and these positions and movements depend in turn on the activity of several muscles. Given the complexity of the relationships between the processes involved in articulation, voicing and respiration it is not possible to use single measurements at one level to infer information about what is going on at another level. For example, studying the onset of laryngeal muscle activity by means of electromyography does not provide comprehensive information about the movement patterns of the vocal folds. Additional information should be recorded by electroglottography, photoglottography or fiberendoscopy. Only simultaneous measurements at a number of levels can give comprehensive information. For instance, from the simultaneous recording of laryngeal EMG activity and vocal fold movements by means of EGG one could derive enough information to describe how long it takes to close the vocal folds in order to build up subglottal pressure to initiate phonation. If these measurements are to be interpreted as reaction times it is also necessary to have some information on the state of abduction of the folds prior to the onset of the EMG activity.

Most of the presently available knowledge on the physiology of speech production derives from studies with normal subjects. During the last decade, however, a body of results from physiological measurements on stutterers has accumulated. We will review the relevant research in the next section.

4.3 SPEECH PHYSIOLOGICAL RESEARCH IN STUTTERING

From the preceding section it appears that fluent speech production requires a correctly coordinated interaction of respiration, phonation and articulation. Stuttering might have its origin in a specific deficiency in one or more of the subsystems, and/or in the inadequate coordination or timing of the subsystems.

In this section speech physiological research in stuttering is reviewed.First, research is described which focusses explicitely on a single subsystem, viz. (a) respiration, (b) phonation and (c) articulatory behavior. Second, a review is given of research which is concerned with the coordination of the subsystems involved in speech production.

a. Respiration. Fixation of respiratory structures, disturbed reciprocal relationships between thoracic and abdominal contractions and tremors in respiratory musculature during the moment of stuttering have been observed in a number of studies (see Van Riper, 1982).

Despite the fact that stutterers' breathing patterns have been an important topic for many therapies in stuttering, there is hardly any systematic research into the aerodynamic processes in stutterers' speech. Only intra-oral pressure during dysfluent speech was studied by Hutchinson (1975). The results of this investigation demonstrated several distinct supraglottic aerodynamic patterns associated with stuttered speech. So for instance repeated elevations in intraoral pressure which were successfully released and followed by the appropriate transitions into the following phonetic element characterized sound repetitions. Detailed knowledge with respect to the role of aerodynamic processes in speech motor production in stuttering is still wanting. One original approach to the study of the aerodynamic aspects of stutterers' speech will be described in detail in Chapter 6 of this book.

b. Phonation. Modern research into the physiology of the larynx in stuttering started in 1975 with Freeman and Ushijima's (1975) observations of abnormal laryngeal activity in stuttering from recordings of muscle action potentials by means of hooked wire electrodes. Freeman & Ushijima (1978) reported high levels of laryngeal muscle activity and disruption of normal reciprocity between abductor and adductor muscle groups during stuttering. Shapiro (1980) confirmed these results and also reported the presence of excessive muscular activity during the production of perceptually fluent utterances. By fiber-nasolaryngoscopy Conture et al. (Conture, McCall & Brewer, 1977; Conture, Schwartz & Brewer, 1985) detected differences in laryngeal behavior among various types of stuttering. During sound prolongations the vocal folds were more likely to be adducted and less variable in their movement than during sound/syllable repetitions. In an electroglottographic study Conture, Rothenberg and Molitor (1986) found that normally fluent children exhibited significantly more typical EGG patterns during CV/VC transitions than did young stutterers. They suggested that a number of children tend to have subtle difficulties in stabilizing and controlling laryngeal gestures even during speech that is judged to be fluent, particularly at those points in the utterance where these younsters must move between sound segments. In an investigation of laryngeal timing parameters (voice onsets and offsets), Jenssen, Cherry & Brown (1983) did not find any significant difference between the nonstuttering, mild stuttering, and severe stuttering group. Only severe stutterers had a tendency to show consistently longer mean vowel durations and they also failed to continue voicing during intervocalic /b/ which was the characteristic pattern in mild stutterers and nonstutterers. From these results Jensen c.s. concluded that especially severe stutterers demonstrate more difficulties in the timing of laryngeal activity. Analysing vocal fold movements during stuttering by means of electroglottography, Weiner (1984) suggested that stuttering events share certain phonational attributes. They concluded that stutterers during the moment of stuttering are engaged in one way or another in attempts to initiate and sustain a steady vocal fold vibration. The individual stutterer seemed to use a few characteristic strategies for arriving at a fluent utterance which manoeuvres may be said to make the stutterers' style of dysfluency. Stutterers' fluent productions, however, did not differ from those of normal speakers as seen from the viewpoint of glottographic visualization. A similar conclusion was also obtained by Borden, Baer & Kenney (1985). They reported that electroglottographic and acoustic waveforms of the first few glottal pulses of voicing in fluent utterances of stutterers resembled those of control subjects. After dysfluencies, however, the stutterers seem to start phonation with a more gradual onset.

From all these experiments on laryngeal behavior, employing electroglottographic (EGG), electromyographic (EMG), and fiberscope techniques it can be concluded that there is abnormal laryngeal behavior during periods of dysfluency as evidenced by inappropriate abductory and/or adductory behavior of the vocal folds and by high levels of muscle activity. There remains some controversy as to whether stutterers (as a group) differ from nonstutterers (as a group) in their laryngeal behavior during perceptually fluent utterances.

c. Articulatory behavior. Fibiger (1977), recording electromyographic activity of the lip muscles, reported that the mean duration, as well as the variance of the durations of EMG activity related to the release in labial stop consonants is much higher in the group of stutterers than in the group of nonstutterers. Also the maximum level of muscle activity during the release was twice as high in stutterers as in nonstutterers. This difference appeared much stronger in initial sound position than in non-initial sound position. From these results Fibiger concluded that stuttering behavior is linked to a temporal disorder of the coordination of articulatory movements in the initial stage of speech production. Zimmermann (1980a, b), used high speed cineradiofluorographic techniques to describe the movements of lower lip and jaw in fluent as well as dysfluent speech. He found that during the production of perceptually fluent speech utterances stutterers differed in systematic ways from nonstutterers. In fluent utterances stutterers showed consistently longer transition times between the various articulatory movements, longer steady state positions and longer intervals between movement onset and peak velocity for the lip and jaw. Stutterers showed longer latencies for the onset of articulatory movements as well as voice onset time and they also demonstrated a greater asynchrony between lip and jaw movements. In dysfluent speech utterances of stutterers consistently interarticulator repositioning preceded the termination of an oscillatory movement in the articulators during repetitions or the static position of the articulations during a blockages.

Cross (1983), using a strain gauge system for measuring jaw movements at different speech rates, found that in general, compared with nonstutterers, the stutterers exhibited longer durations for a jaw opening movement, with the largest difference during a slow speaking rate condition. Further, stutterers showed slower and more variable jaw velocities at each of the three speaking rates. Also stutterers demonstrated longer latencies between the onset of the jaw opening movement and the onset of voicing.

Recently, Alfonso, Watson & Baer (in press), using X-ray microbeam pellet tracking to monitor the movements of jaw, lips, tongue and velum, found that for all four articulators the data from a nonstutterer show a more linear and less variable relationship between the onset of displacement and the timing of peak velocity than did the corresponding data for the fluent utterances of a severe stutterer. The range of vertical displacement for each of the articulators seems to be greater for the stutterer than for the nonstutterer. In other words stutterers seem to achieve the same acoustic target with a greater range of articulator movements.

A different perspective on motor control in articulation was suggested by Caruso, Gracco & Abbs (1987). They investigated sensorimotor mechanisms in speech motor control in fluent speech utterances by introducing unanticipated perturbations in lower lip movement during oral closing for /p/. It was shown that all stutterers demonstrated compensatory labial EMG activity and movement compensations. However, upper and lower lip movement compensations to load perturbations were reduced compared to nonstutterers. In an experiment in which they tried to elicit perioral reflex responses there were no indications of hyperactive perioral reflexes in stutterers. Overall, in this investigation the stuttering subjects responded in a somewhat different manner than normally fluent speakers in that stutterers showed consistently longer latency values of labial EMG activity, smaller changes in levels of EMG activity, and smaller changes in magnitude of upper and lower lip movement.

From the research on articulatory behavior it can be concluded that in stutterers' fluent speech utterances the timing of articulatory movements shows a number of differences compared with nonstutterers. Stutterers show longer delays of movement onsets, longer transition times and longer steady state postures. In addition, they also show more asynchrony between lip and jaw movements.

The interaction between respiration, phonation and articulation. The last group of experiments consists of work on the timing relationships between the subsystems involved in speech production, viz. respiration, phonation and articulation. Research by Ford & Luper (1975) who recorded five speech measurements simultaneously (vocalization, intraoral pressure, subglottal airpressure, EMG activity of the orbicularis oris inferior and the depressor labii inferior), showed within subjects consistent and individualized patterns of physiological activity employed during stuttering. Their results also indicate that apparent discoordination of motor activity may precede, accompany or follow the onset of phonation and that the most obvious disruptions of speech production processes may appear to originate in different parts of the speech production mechanism. Yoshioka and Löfqvist (1981), in examining the acoustic signal in parallel with observing the glottal opening and closure gestures by means of photoelectric glottography, could detect temporal disruptions in the control of abductory and adductory gestures of the glottis in relation to supraglottal articulation and respiratory activity in fluent as well as dysfluent speech utterances of stutterers.

The timing in the initiation of articulatory and phonatory movements was investigated by Janssen, Wieneke and Vaane (1983) through electromyographic recordings of articulatory muscles and electroglottographic recordings of glottal vibration. In general, the mean length of the intervals between the start of various articulatory movements and the onset of phonation as well as the mean interval length between the onset of the various articulation movements did not differ significantly between stutterers and nonstutterers. However, stutterers as a group consistently were more variable in the duration of the various intervals in initiating their speech movements.

Watson and Alfonso (1984, 1987) monitoring respiratory and laryngeal movements by respitrace and transillumination instrumentation respectively, showed differential deficits in the timing of respiratory and laryngeal movements for mild and severe stutterers. Severe stutterers demonstrated significant delays in attaining vocal fold closure as well as the organisation of prephonatory respiratory and laryngeal movements, while mild stutterers only demonstrated a delay in vocal fold closure.

Concluding remarks : From the experimental work reviewed in this section, a number of conclusions can be drawn:

First, In comparison to nonstutterers stutterers often show: Longer delays in the onset of laryngeal and articulatory movements, slower movements and longer steady state positions of the articulators, unusually high levels of muscle activity, aberrant interarticulator positions and a greater range of articulatory movements in achieving the same acoustic target. These features in general result in a higher reactivity and more difficulty in moving smoothly from one articulatory position to another.

Second, perceptually fluent speech utterances of stutterers may show physiological irregularities.

Third, disturbances in stutterers' fluent speech are not restricted to a single locus but may be located in the respiratory, the phonatory or the articulatory processes as well as in the coordination between these processes.

All these unusual features seem to be related in one way or another and indicate that stutterers possess a poor ability to coordinate respiration, articulation and phonation in fluent as well as in dysfluent speech. However, the above account of all these unusual speech features remains on a more or less descriptive level. In the following section these abnormal speech characteristics will be viewed from a number of different theoretical perspectives.

4.4 STUTTERING AS A DISORDER IN SPEECH MOTOR PRODUCTION

During the last decade a large number of different approaches to stuttering as a speech motor disorder have emerged. These approaches vary from those that focus more specifically on peripheral processes to approaches in which stuttering is described as a deficiency of the higher central nervous system. It is not easy to make a clear and unambiguous distinction between these different approaches. Not only do most of these views share some "common-ground", but the fact that different disciplines deal with the topic of stuttering, each from it's own point of view, creates some difficulty in defining, comparing and interpreting the claims made in each approach or description. It is not the purpose of this section to present a comprehensive outline of all approaches but only to mention the most influential ones. In the description, the more peripheral approaches are described first, followed by those that claim more central processes involved.

Adams (1974, 1975), described stuttering primarily as a defect in airflow and vocalization. Speech disruption in stuttering is described as a breakdown in the timing, the smooth initiation and the maintenance of exhalation and voicing. When this occurs the stutterer either repeats the same articulatory gesture or prolongs the articulatory posture being attempted. Adams explained stuttering as resulting from the combined effects of insufficient transglottal air pressure and excessive glottal resistance. The insufficient transglottal pressure may be the result of insufficient subglottal pressure and excessive supraglottal pressure, while the excessive glottal resistance may be due to either excessive stiffness of the vocal folds or tightly adducted vocal folds prior to phonation. Supraglottal stutterings may inhibit voicing by increasing supraglottal pressure, while glottal stutterings may inhibit articulatory transitions. This results in a two-way discoordination within the adult stutterer. Reduced stuttering should occur if the role of one of the systems (phonatory or articulatory) is eliminated or greatly reduced, because then coordination will be much simpler.

According to Wyke (1970, 1974a,b) stuttering should be explained as a phonatory reflex disorder. Following from his assumptions on laryngeal reflex mechanisms during phonation stuttering is viewed as being the result of either a disorder in the prephonatory control system or a disorder in the reflex maintenance system during phonation. In this way Wyke distinguishes two varieties of stuttering as far as the larynx is concerned, namely (1) "voluntary or cortical stuttering", resulting from premature abnormally slow or inaccurate voluntary presetting of the laryngeal (and/or respiratory) musculature, and (2) "reflexogenic stuttering", resulting from insufficient or disorganized reflex maintenance of this preset pattern of muscle tone because of abnormal temporal relations in the operations of one or more of the laryngeal reflex system (Wyke, 1974, p. 133).

More recently, Zimmermann (1980c) developed a motor model in which the role of neurological reflex system is explained in more detail. On the basis of his cineradiographic studies of the temporal and spatial patterning of lip and jaw movements and on voice reaction time research Zimmermann (1980a, b), states that disfluent behavior is "caused by changes in reflexological interactions among the respiratory, laryngeal and supralaryngeal structures". In fluent speech the articulators are moving within certain ranges of velocity and displacement and within certain ranges of intra-articulator positioning and timing. If these ranges are exceeded interarticulator reflex pathways become abnormally facilitated or inhibited resulting in repetitions or blocks. The inability to control this reflex activity would result in an imbalance, reflected in instability and oscillation, or in more general disruptions of motor performance. By keeping velocity of movement down and by using more time to complete a gesture a stutterer will not exceed the range of variability and will remain fluent.

Neilson (Andrews, Craig, Feyer, Hoddinott, Howie and Neilson, 1983) describes stuttering as a deficiency in the central capacity to integrate sensory information from the speech apparatus with motor output and thereby causing inadequate efferent (motor) signals to the muscles. Neilson hypothesizes that stutterers have a diminished ability to deal with the relationship between motor or efferent activity and the associated sensory or reafferent activity produced during speech. As a consequence if he wants to speak fluently the stutterer must spend some extra time dealing with this relationship or he must use additional capacity at the expense of other functions. This inadequacy may be inherited in terms of a particular cerebral organisation. Whether one will become a stutterer depends on one's neurological capacity for the sensory-to-motor and motor-to-sensory transformations. From such a view one can hypothesize that speech motor complexity may be an important factor in fluent speech production and consequently it can be predicted that stuttering will worsen in a more difficult and complex speech task.

Van Riper (1982) described stuttering as a disorder in temporal control. Stuttering behavior is described by Van Riper as a "word improperly patterned in time and the speaker's reaction thereto". He holds that stuttering reflects a defect in coarticulatory timing at the level of the syllable. Stutterers possess a decreased ability to time or integrate long motor sequences which consequently leads to the production of sequences with inappropriate coarticulation. The stability of the motor patterns that maintain the integrity of syllables is lacking in stutterers because they rely too much on auditory feedback instead of tactile-kinesthetic-proprioceptive feedback. Although not specifying any specific causes for the problem, it is assumed by Van Riper that (1) instability of motor patterns for syllables, (2) the inability to integrate a large number of events in a correct temporal order, and (3) problems within the respiration, phonation and articulation are responsible for dysfluent speech. Together these factors result in fractured syllables characterized by improper coarticulatory transitions between sounds.

More recently MacKay & MacDonald (1984) tried to specify the nature and cause of the hypothesized timing difficulty described by Van Riper from a more general theory of speech motor production. In fluent speech they claim that there are three levels or systems of control, namely a muscle movement system, a phonological system and a sentential system. The first is involved in controlling and coordinating of laryngeal, respiratory and articulatory muscles in speech production. The phonological system controls the sequencing of syllables and phonemes and the sentential systems the sequencing of words in sentences. Each of these systems is supposed to be organized in content nodes. Within the muscle movement system the content nodes represent muscle-specific patterns while within the phonologic and sentential system they represent the cognitive units for controlling movements making up a programmed sequence. Errors within these systems occur "when another node in the domain has greater priming than the intended to-be-activated node" when activation is applied. Repetitions, prolongations and blockages in stuttering may be considered as specific error patterns related to a disturbed priming and recovery cycle. For blockages and prolongations a malfunction in the self-inhibition mechanism is supposed to be responsible. Repetitions are supposed to be the result of some reactivation process due to an abnormal priming and recovery cycle. Anticipatory priming i.e. summation of activation pulses during speech production for subsequent phonemes or words, reduces the probability of stuttering during the utterance. According to MacKay and MacDonald it could be hypothezised that stuttering should be primarily located within the muscle movement system for four reasons, first, stutterers do not report stuttering during internal speech, second, the probability of stuttering increases with the number of movement components involved, third, stutterers appear to have difficulties in initiating speech and fourth, stutterers show no deficits in the perception of speech. High level factors such as anxiety and syntactic ambiguity certainly can also effect motor control at every level and thereby influence the probability of stuttering.

Kent (1984) considered stuttering as caused by a central deficiency resulting in a reduced ability to generate temporal patterns. Stutterers continually contend with a faculty or unreliable mechanism for the control of temporal structure. Fluency inducing manoeuvres generally reduce temporal uncertainty or allow more time for the preparation of temporal programs. In addition to a reduced capacity for generating temporal patterns stuttering may be influenced by the presence of stressors or strains. On the other hand the locus of dysfluency seems to be to some degree syntactically constrained; for example stuttering often occurs at the initiation of the verb phrase. So, both linguistic uncertainty in sentence formulation and temporal uncertainty in speech production may interact to precipitate moments of dysfluency.

Concluding remarks.

Reviewing these approaches in which stuttering is primarily considered as a speech motor problem a number of conclusions can be drawn. First of all it is clear that the claims made by these authors are mostly based on observations made of peripheral structures, like the larynx, or on the interpretations of characteristics of dysfluent speech. The generalization of these findings to some cause for the observed behavior is not usually warranted by the evidence. The fact that most of these views start from a description and interpretation of different types of disruption in the speech process, i.e. the output of the system and then try to infer the inner working of the system implies an important limitation for understanding the underlying mechanisms in dysfluent speech. This leads to increasingly speculative assertions as one moves from peripheral to central origins of the stuttering problem. To avoid excessive speculation most views are constrained to just describing the observed behaviors instead of explaining them. Except for the approach of MacKay and MacDonald, in these views no attempt is made to integrate the findings and the stated view characteristics with a more general model of speech production. As such the approaches reviewed before are far too limited in making predictions of speech motor processes, either fluent, or dysfluent.

4.5 OUTLINE OF THE EXPERIMENTS DESCRIBED IN CHAPTER FIVE TO EIGHT

Research in speech motor production in stuttering is still in its first stage in which it begins to explore in what way speech motor production may be disturbed.

As described in the previous section a large number of different attempts were made to describe stuttering as a disorder of movement. Acoustical and physiological research is already providing various lines of evidence for anomalies of the peripheral speech processes in stutterers in fluent as well as dysfluent speech, viz.:

First, the onset of phonation presents particular difficulties for stutterers. Stutterers show difficulties in producing the appropriate levels of muscle activity (Freeman and Ushijima, 1978; Shapiro, 1980) and coordinated laryngeal activity (Conture et al, 1977, 1985, 1986; Freeman & Ushijima, 1978, Shapiro, 1980). Second, stutterers have difficulties in the appropriate timing of lip, jaw and tongue movements (Alfonso, Watson and Baer, in press; Cross, 1983; Caruso, Gracco and Abbo, in press; Zimmermann, 1980a, b). Third, the coordination or timing of respiratory, phonatory and articulatory movements seems to be more difficult in stutterers than in nonstutterers (Ford and Luper, 1975; Janssen, Wieneke and Vaane, 1983; Yoshioka and Löfqvist, 1981; Watson and Alfonso, 1984, in press). Fourth, stutterers are slower in initiating speech movements than nonstutterers.

The experiments described in this study address three different questions with respect to the onset of speech in stuttering. First, the manifestation of voice onsets on the perceptual and acoustical level is investigated. Second, an important parameter which has not been studied systematically before, viz. the role of subglottal aerodynamic processes in the onset of phonation is studied in detail and third, it is investigated which phases in the onset of phonation are particularly responsible for the longer reaction times observed in stutterers.

Perceptual evaluation of the speech of stutterers in clinical practice suggests that especially a smooth and gradual voice onset seems to pose problems. Thus it is not surprising that a large number of stuttering therapies attempt to improve voice onset. However, there is no well founded research on the perceptual and acoustical aspects of abruptness of voice onset and no standarized methods for describing abruptness of voice onset are available. Therefore, in the experiment which is described in Chapter 5 the perceptual judgment of abruptness of voice onset as a function of acoustical parameters is investigated.

The investigation described in Chapter 6 is focussed on the aerodynamic aspects of fluent speech utterances of stutterers and nonstutterers. In this study, first, the way in which the build-up of subglottal pressure proceeds just before the start of phonation is investigated in stutterers and nonstutterers. Second, it is investigated in which way two speech modification strategies frequently used in stuttering therapy affect the patterns of subglottal pressure build-up.

In Chapter 7 the coordination between respiratory functions i.e. the patterns of pressure build-up and the onset of vocal fold vibration is studied in more detail. In particular, the physiological processes in voice onset underlying stutterers' fluent speech were compared with the corresponding processes in nonstutterers.

Independently of the physiological research reviewed in the previous sections, on the basis of a critical review of a large number of reaction time studies Adams (1984) concluded that stutterers are unequivocally slower in initiating and terminating voicing than nonstutterers. The most relevant aspects of this body of research, which is essentially restricted to the acoustic level, will be presented in the introduction of Chapter 8. There it is argued that the delay in stutterers' speech reaction times may find its cause in different stages of the speech production process, e.q. the planning or initiation. In this context one of the suggestions derived from the review of physiologically based explanations of stuttering is of interest, viz. the conclusion that stuttering appears to be more frequent in longer and more complex utterances. Both aspects are investigated in Chapter 8.

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CHAPTER 5

PERCEPTUAL JUDGMENT OF ABRUPTNESS OF VOICE ONSET IN VOWELS AS A FUNCTION OF THE AMPLITUDE ENVELOPE

Herman F.M. Peters

Louis Boves

and

Ineke C.H. van Dielen

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SUMMARY

Four experienced speakers were trained to produce isolated vowels with different degrees of abruptness of voice onset while keeping the maximum sound level and the duration of the sounds constant. A total of 420 vowel tokens were rated for abruptness of voice onset by 11 trained speech scientists in order to study the reliability of the ratings, which was found to be moderately high ($R_{1,1}$ = .74 with an extremely large range of the stimuli). Next a number of simple descriptions of the rising slope of the amplitude envelope are developed. It appears that the logarithm of the time needed for the amplitude envelope to rise from 10% to 90% of its eventual maximum level is the best predictor of perceived abruptness of voice onset of the measures examined in this study. Based on this result an inexpensive instrument is described that can help the speech-language pathologist in assessing abruptness of voice onset in clinical practice.

5.1 INTRODUCTION

The abruptness of voice onset has frequently been noted as an important factor in the context of voice problems and stuttering. This is not surprising if one realizes that the onset of phonation is the result of an intricate interplay of the respiratory, phonatory, and articulatory systems. Specifically, the onset of a voiced sound depends upon the adjustment of the subglottal pressure, laryngeal musculature, and supraglottic articulators prior to phonation and upon the way in which these change during the first few cycles of vocal fold vibration. It is natural to assume that the maximum amplitude of a voiced sound is reached sooner when phonation starts in a condition where subglottal pressure and medial compression of the vocal folds are high than in a condition where either subglottal pressure or medial compression (or both) are low.

In various voice disorders - especially hyperkinetic dysphonia, vocal nodules, and contact ulcer - an abrupt voice onset (often called abrupt glottal attack) is indicated as a common characteristic in the development of these disorders. Consequently reduction of sharpness of glottal attack and the establishment of an easy onset of voicing play an important role in voice therapy (Aronson, 1980; Greene, 1978; Gunderman, 1977; Wilson, 1978).

Stuttering is a speech problem in which the abruptness of voice onset plays an especially important role. Aberrant laryngeal muscle activity and in appropriate vocal fold positioning has been observed as an important factor contributing to the stutterer's block (Adams, 1976; Bloodstein, 1969; Conture, 1982, 1985; Conture, McCall & Brewer, 1977; Freeman & Ushijima, 1978; Shapiro, 1980; Shapiro & De Sicco, 1982; Van Riper, 1982; Yoshioka & Löfqvist, 1981). Therefore, it is not surprising that many stuttering therapies contain exercises that try to influence the onset of phonation. The aim of these exercises is to arrive at a smoother coordination of several articulatory and phonatory gestures, especially with respect to the build-up of subglottal pressure and the adjustment of the laryngeal muscles. The congruity of the final goals of many therapies should not be obscured by the different practical approaches and the widely divergent terminology: effortless phonation (Adams, 1975), easy voice onset (Agnello, 1975), gentle voice onset (Webster, 1975), airflow therapy (Schwartz, 1976), vocal control (Weiner, 1978), prolongation

(Ryan, 1974; Shames & Florance, 1980) and easy relaxed speech (Gregory, 1979).

Given the importance attributed to the abruptness of voice onset, it is surprising to find that there is virtually no literature on the reliability of auditory judgments of voice onset by speech-language pathologists nor on the consistency with which a certain type of voice onset can be produced by trained speakers. In a similar vein, there are no studies reporting objective measurements of the results of therapies that influence the manner of voice onset. A search of the literature in psychoacoustics showed that there is very little known about the just noticeable differences (JNDs) of rise times and decay times of auditory stimuli. One exception is the work of Van Heuven and Van den Broecke (1979) who found JNDs of about 25% of the rise/decay times of the reference stimuli in a matching experiment. In their experiment rise times varied between 15 ms and 100 ms, and all slopes were linear. In the speech of patients who have gone through one of the therapy programs indicated above, rise times considerably exceeding 100 ms can be expected (Agnello, 1975, 1986; Peters & Boves, 1986; Van Denburg, 1979). Also the rising slope of the amplitude envelope often has another form than a single straight line. As yet, there is no knowledge about the effects of the form of the slope on the perception of abruptness of the onset of an auditory stimulus.

In accordance with the lack of experimental research into the perception of abruptness of voice onset, there is no generally agreed upon method to measure this parameter in actual speech. Such a procedure would be of great help in the speech clinic, especially when it appeares that for some reason the reliability of auditory judgment is not sufficiently high. In order to be of practical value, the procedure should be implemented with a low-lost instrument. Presently, such an instrument is not available. The thing that comes closest is the Voice Monitor, which is used in Webster's Precision Fluency Shaping Program (Webster, 1975), but this special purpose instrument is not suited for general use.

This paper is divided into two parts. The first part addresses the reliability with which trained speech scientists rate the abruptness of voice onset and will touch upon the question of how precisely and consistently people can produce a certain degree of onset abruptness. The second part of the paper investigates the contribution of a number of waveform parameters of the stimuli used in the rating experiment to the perception of abruptness of onset. The results of this research will be used to propose a simple method for the acoustic assessment of voice onset that can be used in the speech clinic.

5.2 JUDGEMENT EXPERIMENT

In order to assess the reliability of expert ratings of voice onset, an experiment was performed in which 11 trained judges rated 420 stimuli. The design of the experiment enabled us to obtain an estimate of the consistency with which specified onsets could be produced by healthy speakers specifically trained for the task.

Speakers

Four 20-year-old males served as the speakers in the experiment. All were advanced students in speech-language pathology, enrolled in the School of Logopedics in Nijmegen. None of the speakers had any voice or hearing problems. Prior to the recording sessions the speakers were trained on the task of producing specific types of voice onset. The training was given by a very experienced voice scientist.

Seven types of voice onset were defined; these definitions of abruptness were usually illustrated for the speakers by means of the graphic representations of the amplitude envelopes shown in Figure 1. The trainer produced a number of examples of each type of onset. Next the trainees were asked to imitate the productions of the trainer, who judged the appropriateness of the imitation. The trainee was given specific instructions on how to adapt his behavior. The training sessions took about two hours. In each session two speakers were trained. During the last part of the training the speakers were familiarized with the procedure that was to be used during the actual recording session, which took place two weeks after the training session.

Recording Procedure

The speakers' task was to produce vowel tokens with different types of voice onset while keeping the maximum sound level and stimulus duration as constant as possible. With this aim in mind the following procedure was used. The speaker and an assistent were seated in a sound treated

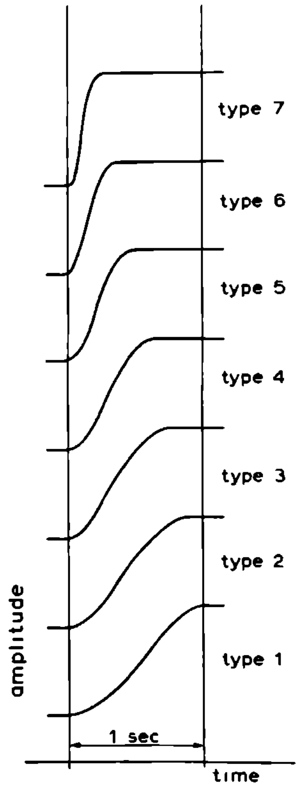

Figure 1: Graphic representation of the seven types of amplitude envelopes produced by the speakers in the judgement experiment.

recording room. Both had visual contact with the experimenter present in the control room, where a technician controlled the recording. One vowel was produced by the speaker in an interval of 12 seconds. The interval started with a 1-S tone, that was audible to both the experimenter and the speaker. Prior to the warning tone the experimenter indicated which type of onset was to be produced by showing a panel containing the type number to the speaker and the assistant. Immediately following the tone, the type number was spoken by the assistant and recorded on tape. Three seconds after the warning tone a light in front of the speaker was turned on for 1 second. The speaker was instructed to start his phonation immediately after the onset of the visual stimulus and to end the vowel at the moment when the light was turned off. In this way equal durations of the stimuli, regardless of the type of voice onset, were guaranteed. Next to the light a Bruel and Kjaer type 2225 integrating sound level meter was mounted, and the speakers were instructed to produce the stimuli in such a way that approximately the same peak sound level was reached in each stimulus. Because the Type 2225 sound level monitor gives a decibel (A) reading, equal peak sound levels roughly correspond to equal maximum loudness. Immediately after the production of the vowel the speaker gave a rating of his own performance by naming the number of the type of voice onset he had actually produced. After this self-rating the assistant who accompanied the speaker also rated the trial and subsequently called out the maximum sound level as indicated by the meter. All these actions had to be performed during the 7 second interval between the offset of the light and the onset of the warning tone of the next trial period.

Because it appeared that the speakers had great difficulty maintaining a constant maximum sound level if they had to produce different vowels, it was decided to break up the recording sessions into three parts, each part devoted to one of the vowels /a,i,u/. All speakers started with the /a/ vowel and ended with the /i/. The voice onsets were produced in a quasi-random order that was different for all speakers. The randomizations were prepared in such a way that each consecutive set of seven vowels contained all seven onset types. Successive randomized sequences of seven trials were offered to the speaker until he had produced at least six tokens of each type of onset of a vowel for which the self-rating and the assistant's rating agreed with the type intended by the experimenter.

At the beginning of each recording session the amplitude controls of the Studer 0-80 Audio Console were adjusted by the technician in such a way that signal clipping was avoided, without sacrificing the signal-to-noise ratio of the recordings. After this initial adjustment the amplitude controls were never changed during a session. For the recordings a Studer A-80 tape recorder and BASF LGR 30 P audiotape was used.

Stimuli

From all 4 speakers, five examples of each voice onset type, for each of the three vowels were copied from the master tape onto a new tape. Because of our impression that not all vowel tokens had the same duration and that there were audible differences in the offsets of the vowels, digital editing and control were used. Experimental tape was digitized using 12-bit amplitude resolution and a 10 kHz sampling frequency. An anti-aliasing filter with a cutoff frequency of 4.8 kHz and a slope of 96 dB octave was employed. A computer program was written that detected the onset of each token. The first 700 ms of each vowel were retained unchanged; the samples making up the next 100 ms were multiplied by a weighting function that tapered from 1 to 0 in the form of a cosine. The resulting stimulus was stored in a disc file. In this way it was guaranteed that all stimuli to be used in the rating experiment had equal durations and comparable offsets.

The 420 digitized and edited voice tokens, i.e., 4 (speakers) x 3 (vowels) x 7 (onset types) x 5 (repetitions of each type) were put into a random order (regardless of speaker and vowel) and after D/A conversion and low pass filtering (using the anti-aliasing filter) re-recorded on audiotape. The stimuli were separated by response intervals of 5 seconds. Blocks of ten stimuli were separated by a 350 Hz tone and an extra 5 sec. pause. Blocks of 20 stimuli were separated by a 1-kHz tone and again an extra pause of 5 seconds. A block of 10 practice stimuli was recorded before the first experimental stimulus.

Judges

The stimulus tape was played to 11 raters. Six of them were speech-language pathologists employed at the department of Speech Pathology. The remaining 5 judges were members of the staff of the Institute of Phonetics. None of the raters had acted as a speaker in the experiment. The judges asked to rate the onset of all stimuli on the experimental tape on a 7-point scale, where the left hand category was marked "extremely soft", the right hand category as "extremely hard", and the middle category as "average". All judges performed the task individually, but the pace of the experiment was completely determined by the stimulus tape, which they listened to only once. The judges were, however, allowed to adjust the tape recorder's volume control to obtain a comfortable loudness level, and they were allowed to take one or more breaks at their own discretion. None of the judges received any payment.

Results and Discussion

In this section we will first present and discuss the results of the analysis of the reliability of the ratings of the abruptness of voice onset. Subsequently we will discuss the relative success of the speaker attempts to produce the various types of onset.

A large number of reliability coefficients have been described in the literature. Essentially, all coefficients are based on an analysis of variance approach to the judgment data. Thus, the differences between the coefficients reflect different assumptions with respect to the analysis of variance model that is most appropriate in a given situation. In our work, we are interested in the reliability of a single, "typical" rater because in most clinical situations usually one rater is available. Moreover, we are interested not only in the correlations between the ratings of several judges but also in their agreement in using the scale, for if decisions have to be made concerning the necessity of the start or continuation of voice therapy, one needs absolute rather than relative judgments. Finally, we wanted to treat the judges as a factor in our experiment. Because none of the judges had special training rating the abruptness of voice onset, we decided to treat the judges as a random factor. This implies that the results of our study can safely be generalized to other experiments employing professional speech scientists as raters. The stimuli form was the second, random factor in the design (Winer, 1971, p. 285ff). Bartko (1966) has shown that under the given model, the reliability in the form of the intraclass correlation $r_{1,1}$ is given by

$$r_{1,1} = \frac{MS_{items} - MS_{res}}{MS_{items} - (n-1).MS_{res} + \frac{n}{k} \cdot (MS_{judges} - MS_{res})}$$

where n is the number of raters, k the number of items and MS_{res} = MS_{error} - MS_{judges}. Obviously $r_{1,1}$ is not only dependent on the agreement between the judges (complete agreement meaning that MS_{error} = 0) but also on the true variance of the items. The latter aspect has been taken care of in this research by guaranteeing the presence of a large range and a supposedly uniform distribution in the stimulus material. The averaged scale values of the items, derived by treating the scores on the successive interval scales as interval data, ranged between 1.09 and 6.64. The distribution of the average scale values was not completely uniform; values between 3 and 5 were slightly overrepresented, whereas the

Table 1: Summary of analysis of variance and reliability data for the complete set of 420 stimuli and two subsets, obtained by removing the items in the upper and lower 5 or 10 percentiles.

Component of variance	Complete data	Extreme 5 percentiles removed	Extreme 10 percentiles removed
MS_{items}	26.16	21.26	16.92
MS_{judges}	41.03	41.53	41.50
MS_{error}	0.82	0.85	0.89
MS_{res}	0.72	0.75	0.77
$r_{1,1}$	0.74	0.68	0.62
$r_{11,11}$	0.97	0.96	0.95

opposite is the case with values <2 and >6. This result reflects the often noted tendency of judges to avoid the extreme categories on successive interval scales (Boves, 1984).

There was little difference between the judges; the averages of their scores ranged from 3.18 to 4.14. Table 1 summarizes the relevant measures needed to compute the reliability of the ratings. The first data column pertains to the complete set of 420 items. The middle and the right hand data columns pertain to subsets of the data, obtained by deleting the 42 and 84 items with the most extreme average scores. From Table 1 it can be seen that $r_{1,1}$ = .74 for the complete stimulus set, and that the reliability coefficient decreases to .62 when the 20% of the items with the most extreme scores are discarded. From the values of MS_{items} and MS_{judges} it can be seen that the drop in reliability is almost completely due to a decrease in MS_{items}. This shows that the reliability measure is not artificially inflated by the inclusion of a small set of extreme stimuli on which the raters reached almost perfect agreement.

The bottom row in Table 1 lists the effective reliability $r_{11,11}$, (i.e., the reliability of the averaged scores on the items employing 11 raters). It can be seen that the reliability of the average values remains very high (.95) even if the 20% of the items that are most extreme are removed from data.

In general, it can be said that the reliability of a typical speech-language pathologist in rating the abruptness of voice onset is fair under the conditions of the present experiment (i.e., when the stimuli to be judged consist of isolated vowels of equal duration and equal offset). Under the same conditions a very high reliability can be obtained if the scores of a number of trained raters can be averaged. Given the strict control of the homogeneity of the stimuli in our experiment, the reliability measures obtained here must be considered as psychoacoustic maxima. In a pilot experiment using VC words produced without control of peak sound level and duration a value of $r_{1,1}$ = .67 was obtained (120 stimuli, 9 raters) that dropped to .40 after removal of the 20% most extreme stimuli (Peters, Boves & Cox, 1984). Because the situation in a clinic is more like the pilot experiment than like the one in the present study, we estimate that in general the reliability with which a speech-language pathologist can judge the abruptness of voice onset warrants the use of an acoustic aid, provided that the latter is easy to use and inexpensive. Apart from the reliability of the raters, the validity of the ratings was also of interest. Given the (as yet unknown) physical characteristics of the stimuli, the validity of the ratings is difficult to estimate. We can, however, obtain some insight into the problem by examining the correlations between the intended voice onset type and the average scores of the raters.

The values are given in Table 2, together with the data on the peak sound level. From that table it can be seen that the relation between peak sound level and intended type of voice onset is very weak as is the relation between peak level and rated abruptness of voice onset. This finding shows that the speakers were quite successful in achieving constant maximum sound level with each vowel, regardless of the type of

Table 2: Correlations between peak sound level, intended voice onset type and average ratings of abruptness of voice onset.

	Intended type	Average rating
Peak level	.104	.045
Intended type	--	.903

voice onset.

The correlation between the intended type of voice onset and rated abruptness is, however, very high ($>.90$). This finding suggests that our speakers were successful in producing seven different categories of voice onset consistently after 2 hours of training. It also indicates that speech scientists, not specifically trained for the task, do a fair job in discriminating among these categories.

5.3 ACOUSTIC DETERMINANTS OF PERCEIVED ONSET ABRUPTNESS

The graphs displayed in Figure 1, used to illustrate the different types of voice onset to the speakers, show two possibly independent dimensions (viz. the rise time and the form of the slope). It is not known how these parameters affect the perceived degree of abruptness of voice onset. In the procedure used to obtain the stimuli no provision could be made to ensure that the amplitude envelopes produced matched the forms given in Figure 1 exactly. Thus, the form of the rising slope of our stimuli was established post hoc. After having obtained measures of the rise time (defined as the time needed for the envelope to go from 10% to 90% of the maximum amplitude) and the form of the rising slope, we were in a position to assess the relative contribution of these parameters to the perception of the abruptness of onset. For this purpose, both simple correlations and multiple regression techniques were used.

Method

All signal and data processing was done with a Data General Eclipse S/200 minicomputer, using the signals in the disc files created when making the stimulus tape. Thus, all tokens consisted of 8.000 samples, obtained by sampling the original continuous signals at a frequency of 10 kHz using 12 bit resolution.The amplitude envelope of the stimuli was obtained by squaring and adding all samples in a rectangular window with a duration of 40 ms and subsequently taking the square root of the sum. No log-transform was applied to the RMS values because it appeared that the original linear data led to results in predicting the perception scores that were far superior to predictions based on log-data. The window was shifted 25 samples after each RMS computation, resulting in an effective sampling frequency of 400 Hz for the amplitude envelope. When the envelope of a stimulus was available completely, the maximum amplitude value was determined. If more than 1 sample of the envelope had the same maximum value, the leftmost (the first in time) was taken as the location of the maximum. Starting at the maximum, the envelope was searched to the left for the first point with an amplitude less than 90% of the maximum. From that point on the search was continued to the left until the first sample was encountered with an amplitude value less than 10% of the maximum. If, during the search for the 10% point, the amplitude rose again to a value exceeding 90% of the maximum, the previously established location of the 90% point was discarded and replaced by the next point where the amplitude fell below 90%. The search for the 10% point was never continued beyond the location found first. The time interval between the 10% and 90% points was taken as the rise time.

Determination of the form of the rising slope. To determine the effects of the form of the rising slope of the amplitude envelope, a formal description of the measured curves was needed. At a first glance, the contours of the envelopes in Figure 1 suggest the use of an exponential or a polynomial function that could be fitted to the measured time series. The use of such functions to parameterize the envelopes has, however, at least two serious drawbacks. First, the procedures needed to obtain an optimal fit involve the solution of sets of nonlinear equations and, therefore, are very computationally intensive. Second, but equally important, the fit of a single exponential function or of a single polynomial function of known low order will only yield useful results if the amplitude envelope is fairly smooth. In clinical practice we have, however, observed quite irregular envelopes in the speech of patients as well as healthy speakers. Information on this irregularity might get lost in the single function approach. An alternative approach is to fit a polygon to the envelope (i.e., try and find an optimal approximation to the measured time series in the form of a sequence of straight line segments). If the number of line segments to be used in the approximation is known a priori, the parameters of the lines can be determined by means of a nonlinear least squares procedure (Marquardt, 1963). Obviously, this approach has many of the same drawbacks as the use of a single exponential or polynomial of fixed order.

We wanted to avoid the computational problems inherent in nonlinear procedures. At the same time we wanted to retain the possibility of leaving the determination of the order of an acceptable approximation of the envelope to the approximation procedure. Therefore, we decided to follow a strategy developed for the approximation of pitch tracks (Kloker, 1976). In this procedure, the beginning of the time series is first determined. Starting from that point, a straight line is fitted through the first five data samples using a Root Mean Square (RMS) criterion for obtaining the best fit, and the RMS error of the fit is determined. This error is then compared with a reference error, using the well known _F_-test. If the result of the test indicates that the error in the fit does not differ significantly from the reference error, the next data sample is added to the set, and a new regression line is fitted. Again the RMS error of the fit is determined and tested for significance. If the error in the fit still does not differ significantly from the reference error, the procedure is repeated with one more data sample added. If a significant _F_ is obtained, the addition of new samples is stopped; starting from the first sample that is not in the set to which the line was fitted, a new line fit is begun, again using five samples at the start. This procedure is continued until the end of the amplitude envelope is reached.

It should be clear that the approximation procedure described in the preceding paragraph does not yield a unique solution. The number of line segments and the parameters of the lines depend to a certain extent on the reference error used in the _F_-test, as well as on the level of significance used. The latter value was fixed at the .1 level in our work. With an appropriate choice of the reference error, excellent polygonal approximations to the envelopes can be obtained, as can be seen from the examples in Figure 2.

Data reduction With our choice of procedure for obtaining a formal description of the form of the rising slope of the amplitude envelope, each token could yield a different number of line segments. Because data aggregates comprising different numbers of measurements for the objects are ill adapted to the customary techniques for statistical analysis, we decided to reorganize the data in such a way that an equal number of measures would result for all objects. This was done by retaining four measures for each vowel sound (viz. the number of line segments needed to approximate the rising slope of the envelope, the angle with the time axis of the first line segment in the approximation, the angle of the

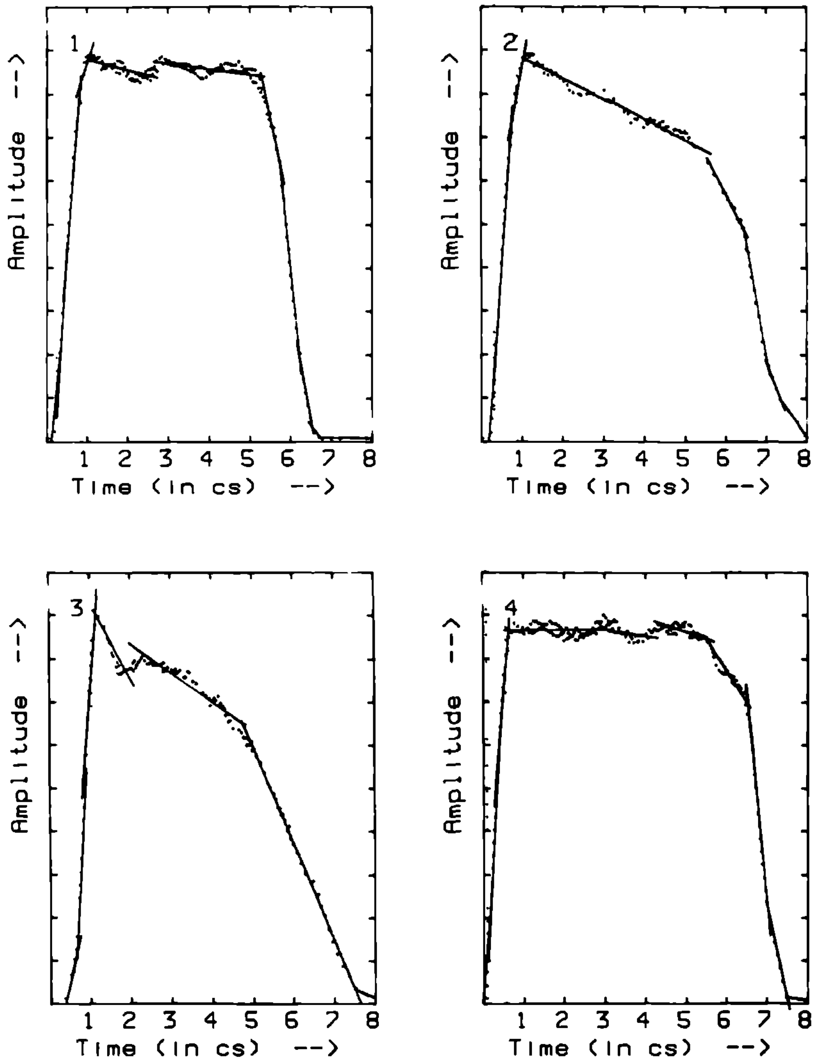

Figure 2: Examples of amplitude envelopes (dotted curves) and their straight line approximations (full, non-vertical lines). Full vertical lines indicate the beginning and end, respectively, of the interval during which the envelope rises from 10% to 90% of the maximum value.

line segment that traverses the greatest part of the amplitude range and the angle of the line that is the steepest). Note that all three angles need not differ for a given vowel. Specifically, if only one line is needed to approximate the rising slope, all three angles are identical. Also, the presence of at least three segments in the approximation does not guarantee that the measures are different because, for instance, the first one may be the steepest. It appeared advantageous to represent the angles by the corresponding tangents.

The choice of measures to represent the form of the rising slope accounts for four aspects that might possibly affect the perception of abruptness of voice onset. The number of line segments needed is an indication of the smoothness of the envelope. The angle of the first line segment should be a useful predictor of perceived abruptness if the perception is determined to a large extent by the very onset of the sound. In a similar vein, the angle of the steepest line would be a useful predictor if the part with the fastest increase of the amplitude envelope determines the perception. The angle of the line that traverses most of the range would be the best choice if the perception is mainly determined by the slope that characterizes the largest part of the envelope.

The combination of the rise time and the four descriptors of the form

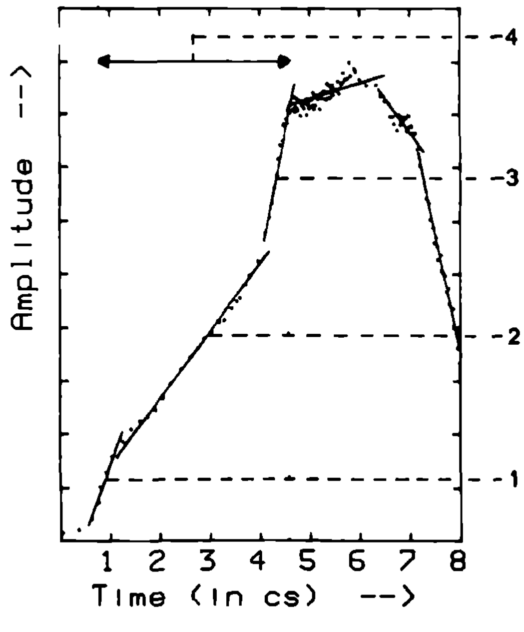

Figure 3: Definition of the measures extracted from the straight line approximations of the amplitude envelopes which have been used to explain perceptual ratings.
1 = First line segment in the approximation;
2 = Line segment spanning the largest part of the amplitude range;
3 = Line segment with the greatest slope, and
4 = Rise time from 10% to 90% of the maximum amplitude.

of the slope gave us five acoustic measures of voice onset. We created an additional measure in the form of the logarithm of the rise time. This nonlinear compression of the range of rise times seemed advantageous because in the region of very large rise times small variations in rise time (e.g. a few milliseconds) are probably perceptually less imported than in the range of very small rise times. The rise time and the slope descriptors are illustrated in Figure 3.

Results and Discussion

Possible relations between the acoustic measures of voice onset and the perceptual ratings of abruptness of voice onset were first explored using product-moment correlations. The results are shown in Table 3. The first thing that strikes the eye is the high mutual correlations between the angles of the first, the steepest, and the largest line segment in the polygonal fit of the rising slope of the amplitude envelope. This result is mainly attributed to the fact that in many items two or three of these measures are identical. In the great majority of the items two line segments were sufficient for the approximation of the rising part of the amplitude envelope. In particular the distinction between the first line and the steepest line seemed to lack significance. Our data do not allow any discrimination between their effects on the perception of abruptness of voice onset.

Another conclusion that can be drawn from the correlation matrix is that the number of line segments needed to represent the rising slope of the envelope is not related to any of the remaining measures. This is due to the very small range of this variable (in no case were more than four segments needed) and, by consequent, its very small variance. Thus, it appears that, at least in the speech of trained, normal subjects, generally the amplitude envelope is sufficiently smooth to warrant an approximation of the rising slope by no more than two linear segments. It must be emphasized, however, that this conclusion may not be generalizable to the speech of patients.

A third conclusion apparent from the correlation data is that the linear and logarithmic measures of the rise time are very highly correlated. However, the log rise time correlates slightly better with the regression lines in the polygonal fit than its almost identical linear counterpart.

If we now turn to the correlation between the acoustic measures of voice onset on the one hand and the averaged perceptual ratings of abruptness of voice onset on the other, it appears that the log rise time accounts for the largest part of the variance in the ratings. Also, the angle measures and the linear rise time are virtually equally successful in explaining the variance in the ratings.

The data in Table 3 are averaged over four speakers and three vowels. We have computed the correlation matrices for the data of individual speakers (averaged over three vowels) and for the data pertaining to individual vowels (averaged over four speakers). These correlation matrices are not shown because they essentially do not provide new information. For all speakers the log rise time appeared to be the best predictor of perceived onset abruptness, ranging from -.742 for speaker 1 and -.862 for speaker 4. For the vowels the correlations between log rise time and the ratings were -.837 for /a/, -.797 for /u/, and -.759 for /i/. Actually for /i/ and /u/ log rise time appeared to be the second best predictor of perceived abruptness; in both cases the angle of the line with the steepest slope accounted for a slightly larger proportion of the variance in the ratings.

Table 3: Product-moment correlations between six acoustic measures of voice onset averaged perceptual ratings of abruptness of voice onset.

	Steepest line	first line	greatest span	rise time linear	rise time log	average rating
#lines in rising time	-.119	-.178	-.211	.058	.096	-.047
steepest line		.971	.853	-.617	-.731	.689
first line			.796	-.579	-.687	.641
greatest line				-.659	-.647	.654
linear rise time					.933	-.686
log rise time						-.783

Returning to the results for the complete data set, we see that log rise time accounts for 63% of the variance in the perceptual ratings of abruptness of voice onset. Regardless of the substantial correlations between log rise time and the remaining useful descriptors of the form of the envelope, one can ask whether the predictions of perceived abruptness can be improved by a combination of log rise time and some other measure. In order to study this problem we performed a stepwise multiple regression analysis. Using a reduction of at least 5% of the free variance as the criterion to stop inserting additional independent variables in the regression equation, the procedure stopped after the insertion of the single most powerful predictor. The same result was obtained for the subsets of the data (individual speakers or individual vowels). Therefore we may safely conclude that in our stimulus material all of the useful acoustic measures of voice onset contain essentially the same information when it comes to predicting perceived abruptness of voice onset. Also, one of the simplest measures, viz. the logarithm of the rise time, seems to be the most powerful predictor. The fact that the logarithmic measure does better than its linear counterpart seems to confirm the impression that the perception of rise time is relative rather than absolute. This finding agrees with the results of Van Heuven and Van den Broecke (1979), who found the JNDs of the rise time to be 25% of the rise time of the reference stimulus.

The fact that log rise time is a more powerful predictor of perceived abruptness than any of the angles of segments in the polygonal fit and the fact that no additional measure appeared to explain a considerable amount of the variance in the ratings that is not accounted for by log rise time might be due to an inherent random component in the slopes measures, caused by our fitting procedure. Having found that for the speech of trained normal speakers two or three line segments suffice to describe the rising slope of the amplitude envelope, it would be informative to repeat the fitting procedure using Marquardt's algorithm, even if one may doubt its usefulness in clinical situations.

It might be interesting to speculate on additional factors that may have influenced the abruptness ratings and therefore could explain the 37 percent of variance in the ratings not accounted for by log rise tissue. None of the stimuli had an amplitude envelope sufficiently steep to suspect spectral splatter as an additional one. Yet, spectral differences in the first part of the stimuli, probably caused by different adjustments of the larynx in extremely abrupt and very gentle onsets, may have played a role. This suggestion will be tested by repeating the perception experiment with synthetic rather than naturally produced stimuli so that known combinations of amplitude envelopes and spectral content can be

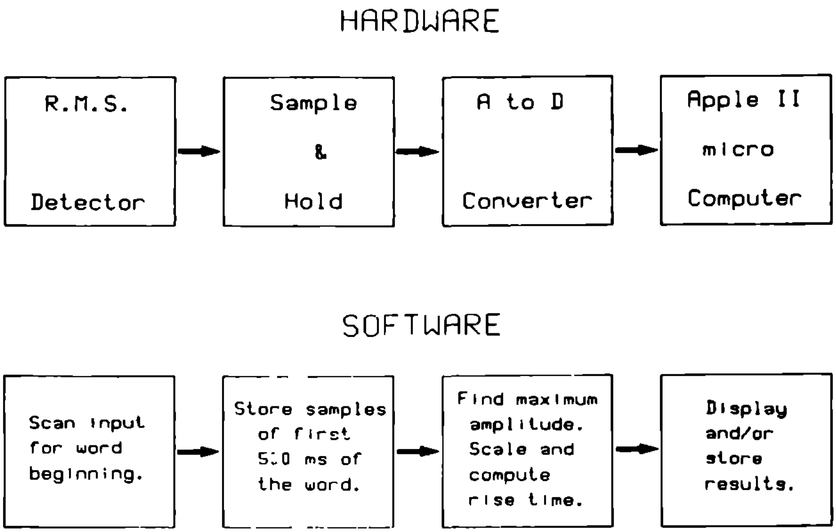

Figure 4: Block diagram of a simple set-up for determining the steepness of voice onset. The upper part of the figure describes the hardware, the lower part defines the software modules.

employed. However, it should be pointed out that extensive research into the relation between acoustic measurements and perceptual ratings of speech very seldom lead to multiple *R*'s in excess of .8C (Boves, 1984; Van Bezooijen, 1984). Apparently the relation between "dumb" acoustic measures and "intelligent", or at least conscious, human judgments is far from straightforward. Much remains to be learned here.

5.4 A SIMPLE DEVICE FOR ASSESSING VOICE ONSET

The finding that log rise time is a useful predictor of perceived abruptness of voice onset suggests the construction of a simple device for aiding speech-language pathologists in judging voice onset. The acoustic speech signal produced by a client reading a list of vowels is picked up by a microphone, amplified, and fed into a simple RMS-detector circuit that is best realized in analog hardware (e.g., using one of the commercially available integrated circuits). The output of the RMS-detector, after low-pass filtering and amplification, can be fed into a sample-and-hold circuit for subsequent digitization. Employing a sampling frequency of 400 Hz, the digitized amplitude envelope can be fed into a and possibly also its ending. The latter point need not necessarily be detected explicitly. Sampling of the first 800 ms of a vowel should be entirely adequate for the purpose. Another part of the program in the personal computer then detects the amplitude maximum and, finally, determines of the rise time. If one so desires, it is very simple to program the computer to display the scale value assigned to the onset of each word and/or to store the results for later use (e.g., for comparison with the same measures after therapy or surgery). A block diagram of such a system as it is under development at our laboratory is shown in Figure 4.

5.5 CONCLUSIONS

The results of our study allow us to draw a number of conclusions. The first, and for clinical practice the most important one, is that a trained speech-language pathologist should be able to judge the abruptness of voice onset fairly reliably, when the stimuli to be judged are isolated vowels of approximately equal maximum sound level, duration, and offset. It is expected, however, that the reliability of the ratings will deteriorate if the stimuli under judgment are less well controlled. Further research is needed to clarify the role of maximum sound level, duration, and offset on the perception of the abruptness of the onset.

The second conclusion, which is primarily of importance in research situations, is that, in the case of tightly controlled stimulus material, an extremely high effective reliability of rated abruptness of voice onset can be obtained by averaging the ratings of a small number of speech-language pathologists. Furthermore, it appears that speech-language pathologists, after a short special training, are able to produce a specific degree of abruptness of voice onset fairly precisely and consistently.

The last conclusion that can be drawn from our results is that the perception of abruptness of voice onset is to a substantial degree through not completely, determined by the rise time of the amplitude envelope. In our stimulus material the form of the rising slope of the amplitude envelope appeared to be irrelevant. It must be remembered, however, that the stimuli were produced by normal speakers, and all envelopes were fairly smooth. Further research is needed before the conclusion that the details of the form of the rising slope are important conclusion that the details of the form of the rising slope are important may be generalized to vowels with less smooth envelopes. In the meantime, a simple instrument can be constructed that may enable the clinician to check her or his assessment of the abruptness of voice onset in the speech of patients.

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AERODYNAMIC FUNCTIONS IN FLUENT SPEECH UTTERANCES OF STUTTERERS AND NONSTUTTERERS IN DIFFERENT SPEECH CONDITIONS

H.F.M. Peters

and

L. Boves

In: Peters, H.F.M. & Hulstijn, W. (Eds.), Speech Motor Dynamics in stuttering. Wien: Springer Verlag, in press.

6.1 INTRODUCTION

The production of fluent speech requires a precise coordination of respiratory, phonatory and articulatory manoeuvres. A number of authors (Van Riper, 1982; Adams, 1974; Wingate, 1976; Agnello, 1975), have suggested that the failure to coordinate expiratory actions and global adjustment of the laryngeal musculature in preparation for phonation is a major cause of dysfluencies in stuttering. This suggestion seems to be substantiated by recent experimental work of Conture (1977), Freeman (1979), Shapiro (1980) and Yoshioka & Löfqvist (1981), who reported substantial differences in laryngeal activity between non-stutterers and stutterers when producing auditorily fluent utterances. Although there is general agreement on the fact that subglottal pressure must be increased to a certain level before phonation can start, very little is known about the details of the way in which the pressure is controlled. This applies equally to normal speech production and speech production of stutterers. Obviously, there may be interactions between laryngeal behavior preceding phonation and the control of subglottal pressure. In this contribution we will deal with both aspects, but the attention will be focussed on the control of subglottal pressure.

To learn to understand the complex process of phonation, multiple physiological processes on several levels should be measured simultaneously. Using the electroglottogram one can obtain information on the behavior of the vocal folds, because the glottogram reflects the time variations of the area of contact between the vocal folds.

In the present investigation the EGG was recorded as a means for obtaining crude information on the behavior and state of the larynx. For instance, glottal closure necessary to increase subglottal pressure in utterances that begin with a vowel can be detected as an isolated sharp peak in the EGG. Also, the start of phonation can be seen very clearly in the EGG.

Over the years a number of techniques have been developed for measuring subglottal air pressure (Van den Berg, 1960). However, because of the invasive character, the restricted bandwidth of measurements as well as interference with phonation these methods are not very suitable for investigations in continuous speech. Since the introduction of miniature pressure transducers mounted at the distal end of a very thin catheter, subglottal pressure registrations can cover a wider frequency range (Koike, 1981; Boves, 1984). Also, the catheter, if properly positioned, does not interfere with normal phonation and articulation.

If speech is a complex multi-level process, problems in speech production may originate from almost anywhere. Thus it is only natural that different stuttering therapies address different aspects of speech production, according to which parts of the process are considered as responsible for the disfluencies. In fluency shaping programs a large number of different strategies directed towards breathing ("Airflow Technique", Schwartz (1976); "Breath Stream Management", Perkins (1973); "Regulated Breathing Approach", Azrin & Nunn (1974)), phonation ("easy voice onset", Ryan (1974) and Agnello (1975); "effortless phonation", Adams (1975); "gentle voice onset", Webster (1978)) and articulation ("prolonged speech", Ryan (1984); Shames & Florance (1980); "easy relaxed speech", Gregory & Hill (1980)) are used to change these behaviors. It is not clear whether all these aspects must be treated independently or whether one may hope that the results obtained from training at one level automatically will carry over to other levels. In this study we have tried to investigate this carry-over effect by making measurements in three different speech conditions, viz. one which can be considered as normal speech, another in which the subjects employed a very gentle voice onset, and a third that can be characterized as consciously reduced articulatory effort.

The purpose of the present paper is first to decribe the way in which the build-up of subglottal pressure proceeds. Next we try to answer the question whether the patterns of pressure build-up found in perceptually fluent utterances of stutterers are different from the patterns found in the speech of nonstutterers. Thirdly, we would like to know if conscious changes in voice onset affect the patterns of pressure build-up, and if so, whether the effects are different from the results of a conscious reduction of articulatory effort.

6.2 METHODS

Subjects

Fifteen adults male stutterers aged between 19 and 28 years and fifteen nonstuttering males, matched for age, served as the subjects in this experiment. With 5 stutterers and 8 control subjects it appeared to be impossible to insert the catheter for measuring subglottal pressure in a proper way due to a number of practical problems. These problems mostly concern anatomical obstructions in the nasal and nasopharyngeal pathway or hypersensibility of the mucuous membranes. Also, because of its stiffness the catheter sometimes drops besides the vocal folds in the sinus piriformis or in the anterior commissure instead of the posterior commissure. This leaves us with 10 stutterers and 7 control speakers from whom speech material is available for analysis. All subjects had a normal hearing acuity and normal language and voice quality.

None of the stutterers had been enrolled in any kind of therapy during the two years preceding the experiment. Because the measurements are invasive and a somewhat unpleasant experience for the subject, it was decided not to try and make the control group equally large as the group of stutterers. Although this decision may complicate the statistical analysis of the data it can still be warranted. Straightforward analysis will not be possible anyhow since the controls do not stutter. The smaller number of controls produce a larger number of fluent utterances.

Stutterers were classified as mild, moderate or severe stutterers. This classification was based on a combination of scale-ratings of stuttering severity in conversational speech and text reading.

Speech conditions

Each subject was tested under three different conditions. The first condition is referred to as the normal speech condition. In this condition subjects were simply asked to produce the words as soon as possible after the response signal. In the remaining two conditions the subjects were asked to produce the words either with an extremely gentle voice onset or with deliberately reduced articulatory effort. The obligation to respond as soon as possible after the warning signal was repeated in the instruction for the two manipulated conditions, but without much emphasis. The order of the manipulated conditions was balanced over subjects. All subjects started the experiment with the normal speech condition.

All subjects (stutterers and controls) received training prior to the experimental session in order to be able to perform in the manipulated conditions. The training was given by a very experienced speech therapist. Although the training never took much more than about 30 minutes, care was taken to ensure that all subjects had reached approximately the same level of proficiency before the start of the experiment. The criterion was - by necessity - the auditory and visual judgment of the speech therapist. Proficiency in performing a gentle voice onset was considered adequate if the subjects were able to consistently produce vowels with a gradual increase in loudness from hardly audible to normal.In the condition with deliberately reduced articulatory effort subjects must be able to produce intelligible speech with minimal visual lip movements, while maintaining a normal loudness level.

Speech material

The speech material used in this experiment consisted of 80 words in each speech condition. Half of the words were one-syllable words of the VC and CVC type. The other half contained three or four syllables. All polysyllabic words had the main stress on the first syllable. In half of the words the initial sounds were two contrasted vowels /a/ and /o/ and in the remaining half two contrasted consonants /p/ and /s/. All word-initial phonemes occurred with the same frequency in both the monosyllables and in the polysyllabic words. In order to obtain this balance, some of the monosyllables had to be nonsense words. Polysyllabic words do exist in the Dutch language, although a few of them are not used very frequently. The choice of the word-initial phonemes was primarily motivated by the requirements of a more comprehensive study of speech motor behavior in stuttering. For the present experiment we will not distinguish between /a/ and /o/ as word-initial vowels. A distinction will, however, be made between words beginning with a vowel and words beginning with a (voiceless) consonant. In the latter category a further distinction between plosives and fricatives must be made. From the 80 stimulus words three complete lists were constructed by putting the words in different balanced random orders. The lists were intended for use in the three conditions that made up the experiment.

Speech task

The procedure in the speech task basically followed a reaction time paradigm. In the experimental setting subjects were seated in front of a TV-monitor. Subjects were asked to read out the stimuli that were presented visually on the TV-screen. Stimulus presentation was controlled by an Apple II^{+}-microcomputer. A randomization program generated a variable fore-period of 1-3 seconds after an auditory (100 Hz tone during 100 ms) and a visual warning signal (a row of asterisks displayed on the screen). Subjects were instructed to produce the stimulus words as soon as possible after an auditory response signal (a 1 kHz tone lasting 100 ms). After each stimulus word a variable intertrial interval of 3-5 seconds followed before the next warning signal.

Fluency criteria

For this study only those speech utterances have been analyzed which were judged to be spoken fluently. In order to be accepted as fluent a word had to satisfy three conditions. Firstly, there must be a complete absence of any visual sign of struggle in the facial or body movements of the subject before or during the production of the word. The presence of visual signs of dysfluency was established by the experimenter during the experiment. Secondly, the utterance may not contain audible hesitations, prolongations or repetitions. To establish the presence of audible disfluencies after the experiment an audio-recording of subjects speech was independently judged by two trained raters. Thirdly, the word must be produced within a reasonable time span following the response signal.

The percentage of fluent utterances ranged from 16.3 to 100 in the group of stutterers, while in the group of nonstutterers subjects had a fluency percentage of 98.7 to 100.

Instrumentation

A schematic diagram of the instrumentation set-up during the experiment is presented in Figure 1. As mentioned before the experiment was completely controlled by an Apple II^{+} microcomputer. All signals were recorded on a FM recorder (Philips Analog 14) running at a tape speed of 15 inches per second for subsequent processing. Vocal fold activity was recorded by means of an electroglottograph; use was made of the device marketed by Fourcin and Abberton under the name Laryngograph (Fourcin, 1981). Subglottal air pressure was measured by means of a Millar PC-350 micro tip catheter, inserted into the trachea via the nasal pathway and the glottis. The speech signal was recorded using an AKG type C451E condensor microphone.

Thanks to the high tape speed employed the frequency response of all

Situation during the registration

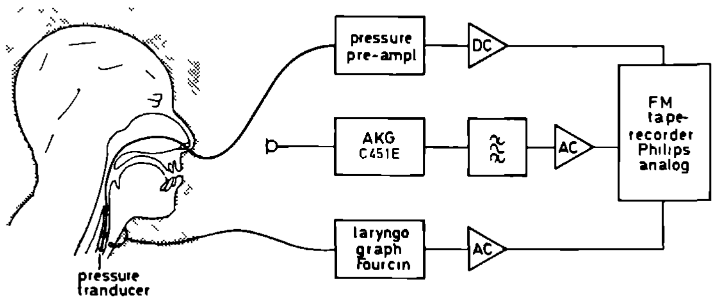

Figure 1: Schematic representation of the experimental set-up during the experiment.

recordings was flat up to at least 5 kHz. The recordings were displayed by playing the FM tapes at a reduced speed into a polygraph. All measurements were taken from these paper recordings made with a paper speed of 5 cm/s.

6.3 DATA ANALYSIS AND RESULTS

The experimental data consisted of 10 x 80 = 800 words produced by the stutterers and 7 x 80 = 560 words produced by control subjects. Of the 800 items of the stutterers 27 words could not be used in the analysis either because of the subjects' coughing in the interval between the warning and response signal, or because of failures of the instrumentation. Of the 773 analyzed words 573 were considered as produced in a completely fluent way. These 573 words form the data base for the stutterers. Of the 560 words produced by the control subjects 7 words were not amenable to analysis due to coughs or failures of the instrumentation and 1 word could not be considered as fluent, so 553 words rested for further analysis.

Pressure build-up

Given the present state of knowledge about subglottal pressure signals it is virtually impossible to subject these signals to a meaningful automated analysis. Therefore, the analysis was restricted to a detailed visual inspection of the signals from the moment of its first rise to the onset of phonation. The latter moment can easily be established on the basis of the appearance of pitch frequency oscillations superimposed on the low frequency traces.

In the attempt to devise a scheme for classifying the pressure envelopes seven different types of pressure build-up were found sufficient to cover the relevant characteristics of the traces. Using our knowledge of the physiology of phonation and the subglottal pressure traces of the nonstutterers as a reference, we concluded that of the seven types of pressure build-up three can be considered as normal, whereas the remaining four must be considered as deviant. The eventual classification of the traces was based on a consensus between the two authors. With very few exceptions the classifications made by the authors when working individually were identical. Where the initial classifications differed, it proved to be easy to reach a concensus after very short discussions. The normal types of pressure build-up (Type 1a, b and c) are shown in Figure 2, the deviant types (Type 2, 3, 4 and 5) in Figure 3. Here we will give a concise description and explanation of each type.

Normal types of pressure build-up

Type 1a This type of pressure build up is the most frequent pattern for words which start on a vowel. The pressure rise as a function of time is monotone and smooth; its overall shape is much like an integral symbol. Phonation starts shortly before the pressure has reached its maximum level. This type of pressure build-up is seen both in VC... and CVC... words. The start of phonation can be determined from the point in time where a high frequency ripple on the pressure curve becomes visible. Similar indications of the onset of phonation are present in the audio signal and in the EGG. This type of pressure build-up corresponds with normal non-abrupt voice onset. Phonation starts from a closed glottis condition. The initial closure of the glottis in preparation for phonation can be seen as a single large amplitude peak in the EGG. Note that this excursion coincides with the moment were the subglottal pressure first starts to rise.

Type 1b. The pressure builds up monotonely with an integral symbol shaped pattern. Phonation only starts at the moment where the pressure reaches its maximum level (both in VC... and CVC... words) or, alternately, some time after the maximum has been reached (only in CVC ... words). In the last case phonation seems to be initiated from an open glottis condition, which is quite normal in words beginning with a consonant.

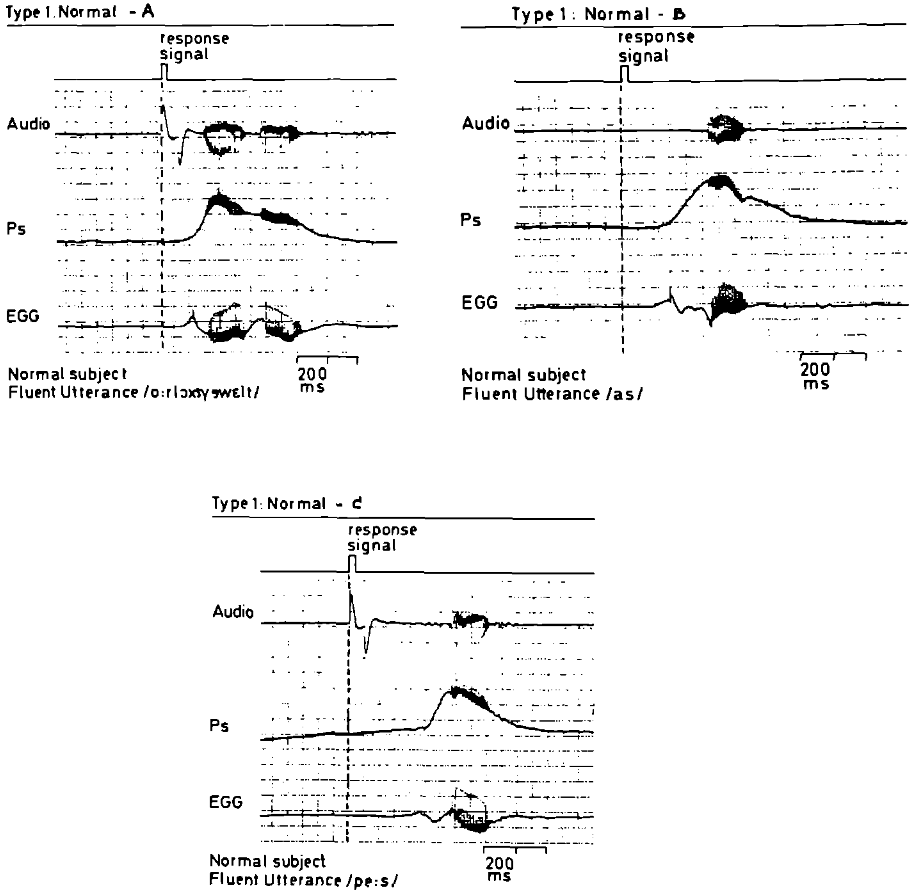

Figure 2: Recordings of normal types of pressure build-up in fluent speech utterances (Type 1A, 1B and 1C). Signals: Audio = Speech Signal; Ps = subglottal pressure and ECG = electroglottogram.

Type 1c Pressure builds up monotonely, with an integral symbol-like pattern from an open glottis and complete closure of the vocal tract associated with stop articulation. However, a small drop of pressure is observed preceding the start of phonation. Phonation starts during pressure recovery or immediately after the moment where the pressure reaches its eventual maximum. In our material this type is restricted to words beginning with /p/. The pressure drop is most certainly associated with aspiration of the consonant, which is not a frequent but neither an abnormal phenomenon in Dutch.

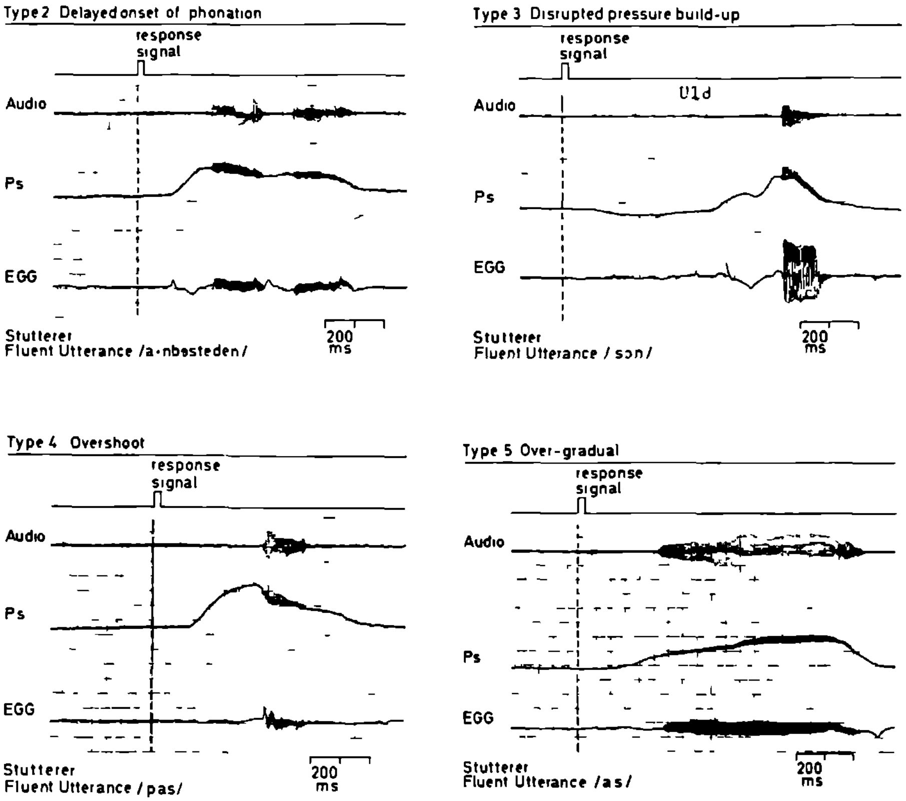

Figure 3: Recordings of deviant types of pressure build-up in fluent speech utterances (Type 2, 3, 4 and 5), Signals: Audio = Speech Signal, Ps = subglottal pressure en EGG = electroglottogram.

Deviant types of pressure build-up.

Type 2. The pressure increases monotonely in a smooth way but phonation starts at least 100 miliseconds after pressure has reached its eventual maximum. This type, which has been restricted to words beginning with a vowel, should be considered as an indication that the speaker is having problems in the coordination of the respiratory and phonatory (and/or perhaps also articulatory) systems. It may perhaps be considered as a very short covert blockage.

Type 3. In this type of pressure build-up the smooth and continuous increase in pressure found in the previous types is disrupted and, therefore, can be described as a non-monotone behavior of the pressure trace before the start of phonation. We consider this type of pressure build-up as a result of problems in the control of the respiratory system or a failure to coordinate expiratory manoeuvres and the concomitant adjustments of the phonatory and/or articulatory systems.

Type 4. In this type the pressure builds up smoothly, usually to a level that is too high for comfortable phonation. After having reached its maximum, the pressure drops considerably before phonation starts eventually. This type can be considered as evidence of an overshoot in the functioning of the respiratory system which is responsible for controlling the subglottal pressure. This type is seen more frequently on words beginning with /p/ than one words beginning with /s/ or /a,o/. Thus it can be considered as evidence of an insufficient coordination of respiratory and articulatory gestures.

Type 5. In this type pressure build-up is exceedingly slow. Phonation starts at a very low pressure level, long before subglottal pressure attains its eventual level. It is closely associated with deliberate and extremely gentle voice onset. Most probably the vocal folds are adducted very gently, perhaps even without touching each other. Therefore, we may not expect to find an indication of glottal closure in the EGG. Consequently, it is not possible to say whether phonation starts from an open or from a closed glottis condition.

Differences between groups and subjects

After having identified the different types of pressure build-up, their frequency of occurrence as a function of the group of subjects and as a function of the speech condition was investigated. The group effects will be discussed first and after that the subject effect. In order to minimize the risk that we are studying artefacts caused by the manipulations of the manner of speech production the analysis was restricted to the normal speech condition.

Group effect. In order to be able to compare the group of stutterers with the control group the absolute numbers of occurrence of the pressure build-up types were first converted to proportions of the number of fluent utterances for each subject. The results for both groups are shown graphically in Figure 4. The numerical data for the individual subjects and both groups are given in Table 1.

From the right hand part of Figure 4 it can be seen that the pressure build-up types 2, 3 and 4 occur roughly with the same frequency. The over-gradual build-up (type 5) is clearly underrepresented in the normal

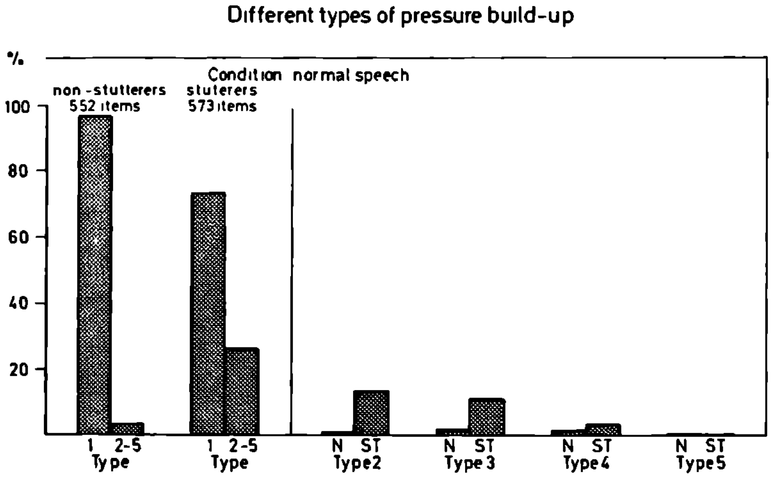

Figure 4: Relative frequency of normal types of pressure build-up (type 1A+1B+1C), the total number of deviant type of pressure build-up (type 1+3+4+5) and individual types of deviant pressure build-up in stutterers (ST) and non-stutterers (N).

speech condition. These remarks apply equally to both groups. The groups differ significantly, however, with respect to the proportion of normal pressure build-up types ($t = -2.675$, $df = 9$, $p < 0.05$, assuming unequal variances in the two populations), and also with respect to the proportion of deviant pressure build-up types ($t = 2.477$, $df = 9$, $p < .05$, again assuming unequal variances). Thus we are forced to conclude that even in perceptually fluent utterances of stutterers the way in which respiratory and phonatory processes are coordinated seems to differ from that in the speech of nonstutterers. This finding confirms previous results of research into glottal activity (Conture et al, 1977; Freeman, 1979; Yoshioka & Löfqvist, 1981).

Subject effect. Table 1 also shows a breakdown of the results for the individual subjects. From this table it appears that there is no relation between the severity of stuttering and the number of occurrence of other pressure build-up patterns than type 1 (Kendall's tau = -0.279, z = -1.127, p = 0.13). This becomes especially clear if one compares subjects 1, 3 and 6 in the group of stutterers. Both 1 and 6 are severe stutterers, but whereas number 1 produces a type 1 pattern in none of his fluent utterances, number 6 does so in 90.6%. The mild stutterer 3, on the other hand, produces a type 1 pattern in no more than 82.9% of his fluent utterances.

Tabel 1: Summary of the pressure build-up data in the normal speech condition. Subjects are ordered on the based of the proportion of fluent utterances in the judgement of stuttering severity (I: mild; II: moderate; III: severe).

Subjects	Stuttering classification	Number of fluent utterances	% fluent	Type 1	Type 2	Type 3	Type 4	Type 5
Non-stutterers								
N 4	--	78	98.7	93.6	--	2.6	3.8	--
N 1	--	80	100	98.7	--	1.3	--	--
N 2	--	80	100	100	--	--	--	--
N 3	--	78	100	94.9	--	5.1	--	--
N 5	--	79	100	98.7	1.3	--	--	--
N 6	--	77	100	96.1	--	--	3.9	--
N 7	--	80	100	96.3	2.5	1.3	--	--
Stutterers								
ST 1	III	13	16.3	--	61.5	46.2	7.6	--
ST 6	III	21	26.3	90.6	4.6	4.6	--	--
ST 2	III	56	76.7	87.5	5.4	5.4	1.8	--
ST 4	I	61	79.2	67.2	24.6	--	8.2	--
ST 7	II	63	79.7	63.5	--	31.7	9.5	--
ST 8	III	60	84.5	75.0	20.0	5.0	--	--
ST 5	III	66	84.6	93.9	--	4.5	1.5	--
ST 3	II	76	97.4	82.9	15.8	1.1	--	--
ST 9	II	80	100	88.8	2.5	1.3	7.5	--
ST 10	II	77	100	88.4	--	14.3	1.3	--
Mean non-stutterers			99.8	96.9	0.5	1.5	1.1	--
Mean stutterers			74.6	73.4	13.4	11.4	3.7	--

Condition effect

Stuttering frequency. In both manipulated conditions the percentage of dysfluencies decreases significantly compared to the normal condition ($F(2,18 = 3,845)$, $p < .05$). In the normal speech condition the mean dysfluency percentage is 26.4; however, in the gentle voice onset condition it is only 6.3; and in the reduced articulatory effort condition not more than 9.8% of the utterances are not fluent. Thus, it is quite clear that a conscious change of the normal speech motor behavior leads to a significant decrease in the proportion of dysfluencies. A post-hoc contrast test shows that the two manipulated conditions do not differ between each other as far as the proportion of stutters is concerned ($t = .607$, $p < .5$). So, for the time being, it seems that any reduction in phonatory or articulatory effort affects the stuttering frequency. Or, alternative ly, it is the fact that attention is focussed on the speech behavior that causes the effect.

Frequency of subglottal pressure types. The effect of the manipulated conditions on the frequency of occurrence of the different types of pressure build-up was very significant as can be seen in Figure 5. In Table 2 the numerical data are given for the individual subjects in both groups for the gentle voice onset condition, in Table 3 for the reduced articulatory effort condition. Both in stutterers and nonstutterers the frequency of over-gradual pressure build-up (type 5) increases dramatically in the gentle voice onset condition. For both groups the effect is significant in a one-way analysis of variance with repeated measures ($F(2,18) = 13.68$, $p < 0.001$ for the group of the stutterers; $F(2,12) = 16.445$, $p < 0.001$ for the control subjects). Thus there appear to be no reasons to believe that as a group stutterers employ physiological strategies for producing a specific auditory result than nonstuttering control subjects. The increase of the number of type 5 pressure build-up patterns goes completely at the cost of the frequency of the type 1 pattern ($F(2,18) = 17.29$, $p < .0001$). The condition of reduced articulatory effort cannot be distinguished from the normal speech condition. As far as the types 2,3 and 4 patterns are concerned, it does not matter whether the utterances are produced normally, with a consciously practiced gentle voice onset or with a deliberately reduced articulatory

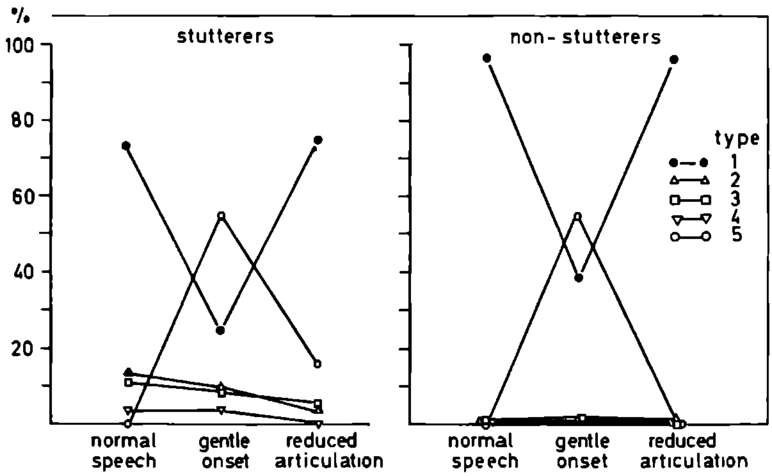

Figure 5: Relative frequency of occurance of pressure build-up patterns in normal speech, speaking with a gentle voice onset and speaking with reduced articulatory effort.

effort. Therefore, the remainder of this section will only be concerned with the proportion of type 5 patterns.

As can be seen from Tables 2 and 3 the effect of the manipulated conditions differs strongly for the individual subjects in nonstutterers as well as in stutterers. While from a perceptual point of view stutterers and nonstutterers manage to produce gentle voice onsets and to articulate with a deliberately reduced effort level after a short training, there seems to be no homogeneous pattern in the underlying physiological processes. Some subjects use type 5 pressure build-up patterns in almost all gentle voice onset utterances (for instance the subjects N4, N5, ST4 and ST5), while others do so only occasionally (subjects N1, ST6 and ST8). Obviously, a specific perceptual speech output can be realized in different ways as far as the underlying

Table 2: Relative frequency of types of pressure build-up for individual subjects in gentle voice onset condition (cf. Table 1).

Subjects	Stuttering classication	Number of fluent utterances	% fluent	Type 1	Type 2	Type 3	Type 4	Type 5
Non-stutterers								
N 4		79	98.7	7.6	--	1.2	--	91.1
N 1		76	98.7	82.8	--	3.9	1.3	11.8
N 2		80	100	77.5	--	--	7.5	15.0
N 3		79	100	18.9	10.1	10.1	2.5	60.7
N 5		79	100	5.1	--	3.8	--	91.1
N 6		77	97.5	64.9	--	--	2.6	32.5
N 7		79	100	15.2	--	--	--	84.8
Stutterers								
ST 1	III	64	84.2	12.5	28.1	6.2	20.3	48.4
ST 6	III	77	97.5	81.8	--	2.6	10.4	5.2
ST 2	III	71	89.9	26.8	9.8	14.8	--	49.3
ST 4	I	76	100	--	--	--	--	100
ST 7	II	70	88.6	48.5	17.1	17.1	7.1	11.4
ST 8	III	54	84.3	53.7	22.2	18.5	1.8	5.5
ST 5	III	69	95.8	7.2	--	1.4	--	92.8
ST 3	II	77	97.5	1.3	5.2	7.8	1.3	84.4
ST 9	II	79	100	5.1	3.8	12.7	--	88.9
ST 10	II	64	100	12.5	12.5	10.9	3.1	73.4
Mean non-stutterers			99.3	38.9	1.4	2.7	2.0	55.3
Mean stutterers			93.7	24.8	9.9	9.2	4.4	55.4

Table 3: Relative frequency of types of pressure build-up for individual subjects in reduced articulatory effort condition (cf. Table 1)

Subjects	Stuttering classification	Number of fluent utterances	% fluent	Type 1	Type 2	Type 3	Type 4	Type 5
Non-stutterers								
N 4		78	100	100	--	--	--	--
N 1		79	100	96.2	--	2.6	--	1.3
N 2		80	100	100	--	--	--	--
N 3		65	98.5	96.9	--	--	--	3.0
N 5		76	97.4	97.4	2.6	--	--	--
N 6		77	98.7	88.3	5.2	1.3	1.3	3.9
N 7		79	100	94.9	1.3	1.3	2.5	--
Stutterers								
ST 1	III	75	94.9	21.3	4.0	8.0	--	69.3
ST 6	III	34	42.5	88.2	5.9	--	5.9	--
ST 2	III	75	93.8	96.0	--	--	--	4.0
ST 4	I	69	93.2	94.2	4.3	1.4	--	--
ST 7	II	76	95.0	80.3	3.9	11.8	3.9	1.3
ST 8	III	57	85.1	82.5	10.5	7.0	--	--
ST 5	III	78	100	46.1	--	1.3	--	52.7
ST 3	II	78	97.5	65.3	3.8	6.4	1.2	23.1
ST 9	II	80	100	97.5	--	1.3	--	1.3
ST 10	II	55	100	81.2	1.8	14.5	1.8	--
Mean non-stutterers			99.2	96.2	1.3	0.7	0.5	1.2
Mean stutterers			90.2	75.3	3.4	5.2	1.3	15.2

physiological processes are concerned. It is interesting, incidentally, that there seems to exist a relation between stuttering severity and the ability to change articulatory behavior. Kendall's tau, computed for the relation between the classification as mild (1), intermediate (2) or severe (3) stutterer and the proportion of type 5 pressure build-up traces in the gentle voice onset condition is tau = -0.47, $z = -1.894$, $p < 0.05$. This might be taken as an indication that severe stutterers are more difficult to train to change their phonatory and articulatory manoeuvres than mild stutterers and nonstutterers.

Another question may be whether subjects with a high relative frequency of deviant patterns of pressure build-up in normal speech have greater difficulty in changing physiological processes. There is no relationship between the frequency of deviant patterns of pressure build-up and the frequency of the overgradual pressure build-up in the gentle voice onset condition (Kendall's tau = -.111, z = -.447, p = 0.33). The impression that there is no clear relation between the frequency of deviant patterns in the normal speech condition and the ability to perform in the manipulated condition is also obtained if one compares the subjects ST4 and ST7. In the normal speech condition 32% and 41% of their utterances have a deviant type of pressure build-up. Whereas subject ST4 produces a type 5 pattern of pressure build-up in all utterances in the gentle voice onset condition, subject ST7 does so only in 11%. Therefore, it seems impossible to predict the specific physiological results of a short and fairly unspecific training on the basis of a single physiological measurement. This result is not too surprising, given the very large number of degrees of freedom on the physiological level, which enables one to produce a given auditory effect in many different ways.

6.4 CONCLUSIONS

From the results of the experiments described in this paper a number of conclusions can be drawn.

The first, and probably most important conclusion is that perceptually fluent speech utterances of stutterers are not always fluent on all relevant levels of speech production. From the data on subglottal pressure build-up it is quite obvious that in fluent speech stutterers significantly more often use unusual subglottal air pressure build-up patterns than do nonstutterers, despite of the very strict criteria for fluency. Thus we see that the physiologic processes, associated with or underlying utterances that seem to be completely fluent on the acoustical level, yet appear to contain a considerable proportion of deviant patterns, that might as well be called covert stutters. This finding, which corroborates previous observations of Freeman (1984), calls into question the outcomes of many other experiments in which perceptually fluent utterances of stutterers have been analyzed. A considerable portion of these allegedly fluent utterances might rather have been considered as physiological stutters and should have been analyzed separately from really fluent (both physiologically and perceptually) utterances.

The second conclusion which can be drawn is that both nonstutterers and stutterers manage to produce gentle voice onsets and to articulate with a deliberately reduced articulatory effort level after a short training in such a way that the performance is adequate from a perceptual point of view. In the gentle voice onset condition, both stutterers and nonstutterers frequently changed the underlying physiologic processes in the sense that they preferred a type 5 pressure build-up.

A third conclusion that can be drawn is that there are indications that the overall severity of stuttering is a better predictor of the difficulty the subject will encounter in performing specific phonatory manoeuvres than the amount of deviations in one of the underlying physiological processes in normal speech production. This illustrates that data obtained from a single process or single level in speech production are inadequate to predict the auditory quality of the speech output.

A last conclusion which can be drawn, is that the effects of the manipulated speech conditions are specific in that they cause different physiological results, which are, moreover, completely in line with our expectations. This implies that in therapy management specific strategies should be used at different levels in speech production and one should not rely too much on the hope that results of articulatory training will carry over to phonation and vice versa. If it is the case that stutterers do not form a homogeneous group in the sense that for some subjects the problems are mainly at the phonatory level and for others at the articulatory level, this finding may help to explain the fact that therapies that completely focus on a single level show widely diverging results, i.e., they succeed only for the subpopulation where the problems originate at the level addressed in the therapy and not for subpopulations where the main cause of the stuttering lies elsewhere.

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CHAPTER 7

COORDINATION OF AERODYNAMIC AND PHONATORY PROCESSES IN FLUENT SPEECH UTTERANCES OF STUTTERERS

Herman F.M. Peters

and

Louis Boves

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ABSTRACT

Problems in the coordination of respiratory, phonatory and articulatory processes have often be thought to be the cause of disfluencies in speech production. However, empirical support for this hypothesis is scarce, because most studies of speech motor behavior are restricted to a single process. This investigation examines the interactions of respiration (specifically the build up of subglottal pressure), phonation and articulation. In particular, the physiological processes underlying the fluent speech of stutterers were compared with the corresponding processes in normal control subjects. Pressure build-up patterns preceding the onset of phonation were studied in 573 fluent utterances of ten stutterers and 552 comparable utterances of seven control subjects. The stutterers used deviant patterns of subglottal pressure build-up much more often than the control speakers. Electroglottographic records of voice onset were classified as either abrupt or gentle. They were also classified with respect to the presence of gross irregularities in amplitude and period duration. Stutterers used an abrupt voice onset significantly more often than controls. The occurence of irregularities did not differ significantly. None of the group differences observed on the physiological level were present in the acoustic comparisons of the same utterances. This corroborates previous findings suggesting that perceptually fluent utterances of stutterers may be physiologically disfluent.

7.1 INTRODUCTION

The production of fluent speech requires a very precise coordination of respiratory, phonatory and articulatory movements. Further, abnormal laryngeal function is an important element in several theories of stuttering. Wyke (1974) and Schwartz (1974) described stuttering as a consequence of deviant reflex mechanisms that disrupt normal laryngeal muscle activity. A number of authors (Van Riper, 1982; Adams, 1974; Wingate, 1976; Agnello, 1975), have suggested that the failure to coordinate expiratory actions and adjustment of the laryngeal musculature in preparation for phonation is a major cause of dysfluencies in stuttering. Adams (1974) and Zimmermann (1980) pointed out that a disruption of coordinated muscle activity within the laryngeal system may be the central factor in stuttering. Others (Van Riper, 1972; Wingate, 1976) have drawn attention to the disruption of coordination between the laryngeal system and the respiratory and articulatory systems.

Physiological studies indicate that the initiation of voicing is particularly difficult for stutterers. A number of different processes in starting phonation were found to be deviant in fluent and dysfluent speech utterances of stutterers. Aberrant muscle activity, including a lack of the normal reciprocity between abductor and adductor muscle groups, was observed by Freeman & Ushijima (1978), Freeman (1979) and Shapiro (1980). Yoshioka & Löfquist (1981) decribed a disruption of temporal control of the abductory and adductory gestures of the vocal folds in stuttering, particularly in relationship to supraglottal articulation and respiratory functions in speech. Conture et al. (1977, 1985) observed inappropriate vocal fold position and hypothesized that a complex interaction among the laryngeal, articulatory and respiratory systems contribute to the occurrence of inappropriate abductory and/or adductory laryngeal behavior. In a study of the programming and initiation of fluent speech utterances (Peters & Hulstijn, 1986a) it was evident that stutterers have longer latency times as well as longer initiation times in starting phonatory movements than do normal control subjects. Recently, Peters & Boves (1986) observed that in fluent speech utterances stutterers use unusual subglottal air pressure build-up patterns before starting phonation more often than normal control subjects.

In fluent speech phonation is initiated by adducting the vocal folds, adjusting the stiffness of the vocalis muscle and the mucosa and increasing the subglottal pressure. For a complete picture of this complex process, multiple physiological processes on several levels should be measured simultaneously. Most of the studies mentioned above, however, obtained data from a single process or a single level in speech production. Given the complexity of the relationships and the level of our understanding of their details, the present knowledge is inadequate to fully characterize the dynamic principles underlying fluent and dysfluent speech (Baer & Alfonso, 1982). Also, a number of different measurement techniques have been used, which makes it difficult to compare results between studies. In general, important limitations in the technical aspects of measurement have prevented a comprehensive description of speech motor dynamics. Research in the coördination of respiratory functions, the adjustment of the larynx, and the start of phonation seems to be especially limited. This study concerns the relationship between aerodynamic functions and the start of phonation in fluent speech utterances of stutterers. To this end simultaneous measurements were made of the acoustic signal, of subglottal air pressure and of the electroglottogram (EGG).

Over the years a number of techniques have been developed for measuring subglottal air pressure (Psg). All these techniques are necessarily invasive. Pressure under the glottis can be measured directly by inserting a hollow needle into the trachea through the skin above the first tracheal ring or by inserting a hollow catheter into the trachea via the glottal opening (Van den Berg, 1960, Ford & Luper, 1975). Both methods, in addition to being invasive, are limited by the restricted bandwidth of the measurement which does not exceed 300 Hz. Since the introduction of miniature pressure tranducers mounted at the distal end of a very thin catheter, Psg registrations covering a wider frequency range are possible (Koike, 1981; Boves, 1984). In this study we used the last method, inserting the catheter into the trachea via the nasal pathway and the glottis.Compared with the method of transcutaneous insertion this method is certainly less invasive; if properly positioned in the posterior commissure, the catheter does not interfere audibly with normal phonation and articulation. A number of problems in using this technique should be mentioned, though. Sometimes the nasal and nasopharyngeal pathway may be obstructed by nasal septum deviations, hyperplasia of the concha inferior or adenoids and/or adenoid vegetations. Hypersensibility of the mucous control subjects it was impossible to insert the catheter properly for the reasons described in the introduction, leaving 10 stutterers and 7 controls membranes can be corrected by using otrivine and lidocaine. After having passed the back of the tongue, the catheter frequently slips behind the epiglottis. In that case special manoeuvres like reinserting the catheter or changing the position of subject's head may be necessary to pass the epiglottis. The tip of the catheter often drops besides the vocal fold in the sinus periformis or in the anterior commissure instead of the posterior commissure because of the stiffness of the catheter (Blok, 1985).

This study was designed to obtain information about the behavior of the vocal folds. Up to a point this can be done using the electroglottogram (EGG). It is by now generally accepted that the EGG reflects the time variations of the area of contact between the vocal folds (Fourcin, 1981; Gilbert, Potter & Hoodin, 1984; Childers, Smith & Moore, 1984). Compared with other techniques of observing vocal fold movements, the EGG has the important advantage of being completely noninvasive. Also, it does not impede normal speech production. These advantages are not shared by techniques like transillumination and ultra-high speed filming.

This report is part of a more comprehensive investigation of the timing and coordination of the respiratory, phonatory and articulatory subsystems in the fluent and nonfluent speech of stutterers. A first report on the overall study (Peters & Boves, 1984, 1986) focussed on the process of prephonatory pressure build-up in the fluent speech of stutterers and controls and on the manner in which patterns of pressure build-up were affected by conscious changes in voice onset and the reduction of articulatory effort. The purposes of the present study are (1) to describe the interaction between aerodynamic and phonatory processes, (2) to describe possible differences between the perceptually fluent speech of stutterers and that of normal speakers, and (3) to see if irregularities in subglottal pressure build-up affect the manner of starting phonation.

7.2 METHOD

Subjects

Fifteen adult male stutterers aged between 19 and 28 years and fifteen nonstuttering males, matched for age, served as subjects. All subjects had normal hearing acuity and normal language proficiency and voice quality. None of the stutterers had been enrolled in any kind of stuttering therapy during the last two years preceding the experiment. For 5 stutterers and 8 from whom data are available for analysis.

Because the invasive technique was unpleasant for the subjects, it was decided not to make the control group as large as the group of stutterers. This decision complicated the statistical analysis slightly, but otherwise did not hinder the comparison. A direct comparison was impossible anyway because the controls did not stutter. The protocol we adopted ensured that we had about the same number of utterances from both groups.

The relevant characteristics of the stuttering subjects are summarized in Table 1. The classification of the stutterers as mild, moderate, or severe is based on the combination of two compound measures, the first of which relates to conversational speech, whereas the other is based on reading text. The individual measures combine ratings of three aspects of speech behavior, viz. the proportion of nonfluent words (P), visible

Tabel 1: Rating scale values on a 3-point scale for conversational speech and reading (P = proportion of non-fluent words; T = visible muscle tension and M = body movements), stuttering severity classification and proportion of fluent utterances in the experimental condition for individual stutters.

	Conversational speech			Reading test			Stuttering severity classification	Fluency percentage experiment
Subject	P	T	M	P	T	M		
1	3	3	3	3	3	3	severe	16
2	3	3	3	3	3	3	severe	77
3	2	2	2	1	2	2	moderate	97
4	1	2	1	1	2	1	mild	79
5	2	3	3	2	3	3	severe	85
6	3	3	3	3	3	3	severe	26
7	2	1	2	2	1	2	moderate	80
8	3	3	3	3	3	3	severe	84
9	2	2	2	2	2	2	moderate	100
10	2	2	2	1	2	1	moderate	100

muscle tension (T) and body movements not directly related to speech production (M). The severity of muscle tension and non-speech related body movements is rated on a three-point scale by an experienced speech-language pathpologist. The number of non-fluent words is counted from audio recordings of subject's speech. The proportions of nonfluent words were categorized as follows: category 1 - less than 10% dysfluent words, category 2 - between 10% and 20%, category 3 - more than 20%. It is our experience that the resulting classification of the stutterers is a valid and useful indication of the severity of their speech problem. Our procedure of classifying stutterers seems to be similar to the one used in Borden (1985).

Fluency Criteria

For this study only those speech utterances have been analyzed which were judged to have been spoken fluently. In order to be accepted as fluent an utterance had to satisfy two criteria. First there could not be any visual sign of struggle in the facial or body movements of the subject directly before or during the production of an utterance. The presence of visual signs of dysfluency was established by the experimenter during the recording session. Secondly, the utterance could not contain audible hesitations, prolongations of repetitions. After the experiment an audio recording of the subject's speech was independently judged by two trained raters in order to check for the presence of audible dysfluencies. All stimuli on which the judges disagreed were deferred to an additional rating session, in which the two judges were both present in order to discuss their original ratings. The purpose of this session was to reach a consensus rating on all stimuli. Experience shows that the majority of the items for which the raters disagreed are readily recognized as containing dysfluencies that were missed by one of the raters during the first rating session. In general, this procedure guarantees that virtually no dysfluent item is erroneously categorized as fluent.

Stimulus Words

The speech material used in this experiment consisted of 80 words. Half of these were one-syllable words of the VC or CVC type. The rest were polysyllabic words containing three or four syllables, with stress on the first syllable. These words contained one or two consonant clusters of at most three consonants each. The initial sounds in this study were two contrasted vowels /a/ and /o/ and two contrasted consonants /s/ and /p/. The four initial sounds were equally represented in the word list. The choice of the initial sounds was primarily motivated by the requirements of a more comprehensive study of speech motor behavior in stuttering (Peters & Hulstijn, 1986a; 1986b). In the present study the initial sounds allowed us to compare the initiation of phonation from a closed (/a/ and (/o/) and from an open vocal fold position (/s/ and /p/).

Speech Task

At each experimental session an ENT specialist and a technician were present, besides the experimenter and the subject. Subjects were seated in front of a TV monitor, coupled to an Apple II+ microcomputer that controlled the experiment. The words were displayed on the TV screen, preceded by an auditory (100 Hz tone of 100 ms duration) and a visual warning signal (a row of asterisks displayed on the screen). Subjects were instructed to say the word as soon as possible after an auditory response signal (a 1 kHz tone lasting 100 ms). The anticipation period between the warning and the response signals was chosen at random from the set |1, 2, 3| seconds. The randomization of the anticipation period served to prevent the subjects from adopting a routine.

A complete experimental session consisted of two parts. In each part the subject had to produce 40 stimulus words (apart from 5 practice stimuli that preceded each half of the experiment). In one part of the experiment the word was shown on the TV screen simultaneously with the warning signal, giving subjects the opportunity to prepare for the articulation of the stimulus during the anticipation period. In the remaining part of the experiment the word was not shown on the screen until the response signal was presented. In this condition, subjects could not use the anticipatory period could to prepare for the articulation. Approximately half of the subjects did the 'preparation' condition first, the rest did the 'immediate reading' condition first.

Instrumentation

A schematic diagram of the instrumentation used for the research is shown in Figure 1. Stimuli were presented by an Apple II+ microcomputer

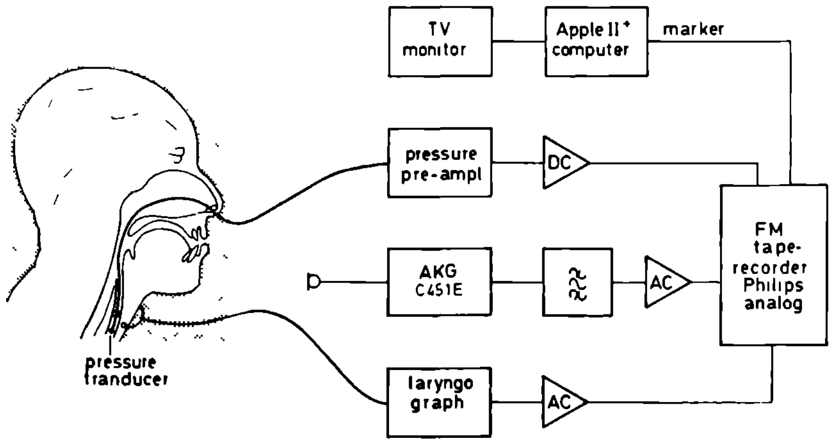

Figure 1: Schematic representation of the experimental set-up during the experiment.

that controlled the experiment. All signals, including the warning and response signals, were recorded on an FM recorder (Philips Analog 14) running at a tape speed of 15 inches per second, which gives a frequency response that is flat within 3 db from DC to 5 kHz. The speech signal was recorded using a condensor microphone (AKG type 451E) placed at a distance of approximately 30 cm in front of the subject. The electroglottograph (EGG) signal was picked up by a pair of gold plated circular electrodes placed on the subject's skin, one at each side of the neck at the level of the thyroid cartilage and recorded by a Fourcin Laryngograph (Fourcin, 1981). The electrodes were held in place with an elastic band fixed around the subject's neck. It is generally accepted now that the EGG reflects variations in the contact area of the vocal folds over time. This voice fundamental frequency signal is superimposed on a signal of much lower frequency, which reflects variations in the positioning of the larynx with respect to the electrodes on the skin. Although this low frequency signal might carry some information on global laryngeal articulation, it is extremely difficult to interpret. Our analysis of the EGG was restricted to the fundamental frequency part of the signal, from which one can extract reliable information about the moment at which vocal fold vibration begins and about the presence of gross changes in the mode of vibration.

Subglottal pressure was recorded by means of a Millar PC 350 Micro tip transducer, connected to a control unit of our own design and construction (Boves, 1984). It is possible to obtain useful estimates of the subglottal pressure by means of a slightly less invasive method, in which the pressure in the oesophagus is measured instead of the tracheal pressure (Schutte, 1980). This technique requires a cumbersome processing of the recorded signals in order to separate the real subglottal pressure variations from interfering components, like changes in lung volume. This makes the technique unattractive for use in our experimental set-up. Therefore, it was decided to adopt the direct measurement procedure, regardless of its obvious drawbacks in terms of inconvenience for the subjects.

Signal Analysis

Analysis of subglottal air pressure signals. The subglottal air pressure signals were classified according to the way the pressure builds up from the moment of its first rise to the onset of phonation. The analysis was made from paper recordings of the pressure, EGG, and audio signals taken at a paper speed of 5 cm/s. Seven different categories of pressure build-up can be distinguished. In the description and interpretation of some types the identity of the word initial phoneme is of crucial importance. The eventual classification was based on a consensus between the two authors. Using our knowlegde of the physiology of phonation and the subglottal pressure traces of the control subjects as a reference, we arrived at the conclusion that of the seven types three can be considered as normal, whereas the remaining four must be considered as deviant in some way or another. The categories and the categorization procedure are described in full detail in Peters & Boves (1986).

The seven types are shown in Figure 2 and 3. A short description of each type follows.

Normal types (see figure 2):

Type 1a. Monotonically increasing pressure; phonation starts shortly before pressure reaches its maximum. This type is seen both in VC and CVC words.

Type 1b. Monotonically increasing pressure; phonation starts just as pressure reaches its maximum level (both in VC and CVC words) or, alternatively, some time after the maximum has been reached (only in CVC words).

Type 1c. Monotonically increasing in pressure; however, a small pressure

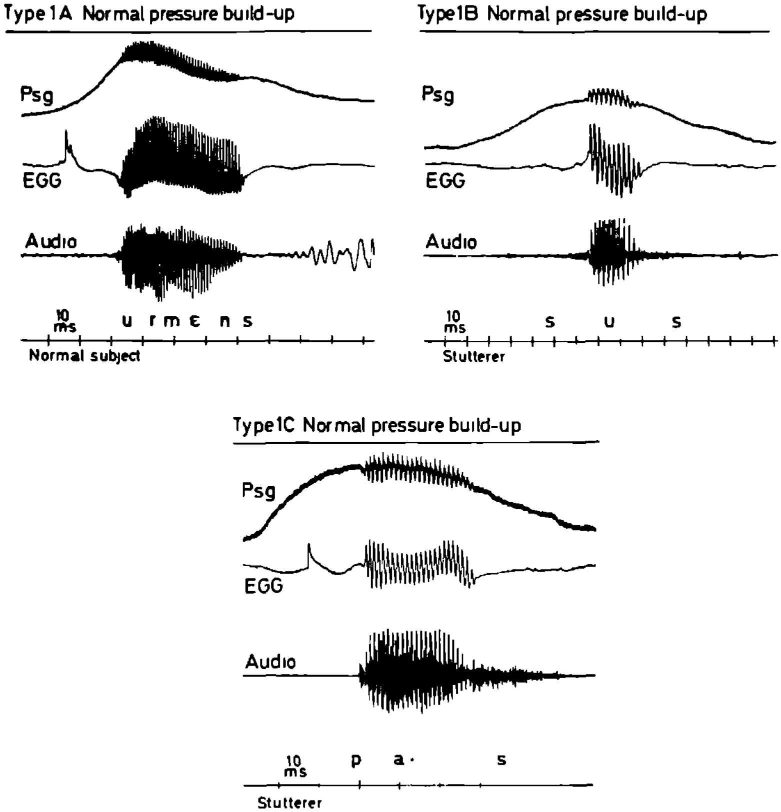

Figure 2: Recordings of normal types of subglottal pressure build-up (type 1A, 1B, 1C). Recorded signals: Audio = speech signal; PS = subglottal pressure and EGG = electroplottogram.

drop occurs before phonation. This type is restricted to words starting with /p/.

Deviant types (figure 3):

Type 2. Monotonically increasing pressure; phonation starts at least 100 ms after pressure has reached maximum. As a deviant type, this is restricted to VC words.

Type 3. Non-monotonically increasing pressure before the start of phonation.

Type 4. Pressure overshoot. The pressure increases - possibly in a monotonic way - to a level that is too high for comfortable phonation. Pressure is reduced to a lower level before phonation commences.

Type 5. Extremely slow build up of pressure; phonation begins at a very low pressure level, long before the eventual maximum level is reached.

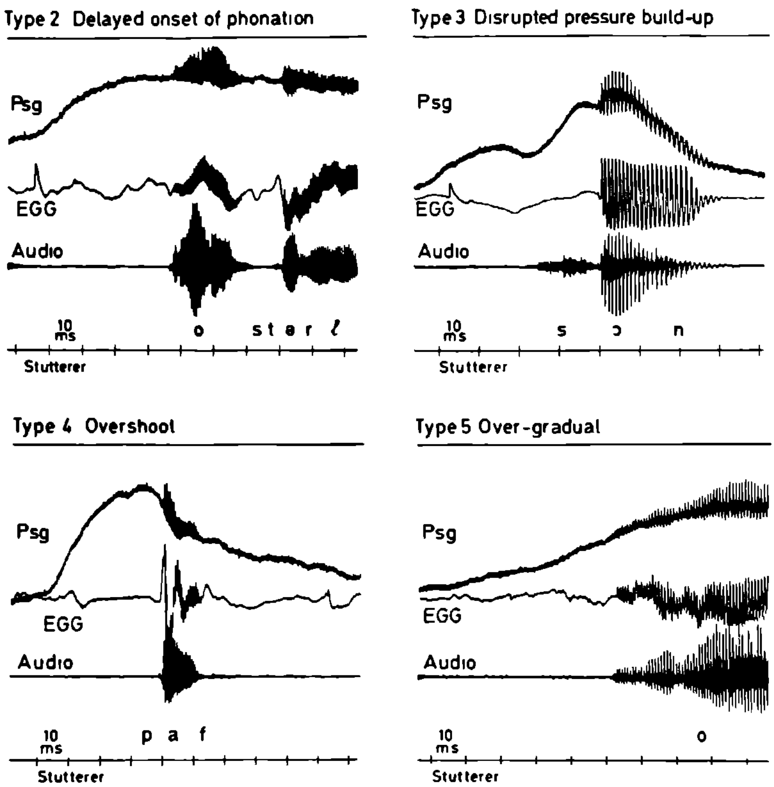

Figure 3: Recordings of deviant types of subglottal pressure build-up (type 2, 3, 4, and 5). Recorded signals: Audio = speech signal; Ps = subglottal pressure and EGG = electroglottogram.

Analysis of the EGG signals. The analysis of the EGG signals was also based on paper recordings, but at a faster paper speed (1 m/s) so that individual pitch periods could be clearly seen. The analysis was restricted to the onset of phonation, taken as the first ten pitch pulses.

The EGG's were classified on the basis of two criteria: (1) the form of the amplitude envelope and (2) the presence or absence of major irregularities in the period duration and/or the amplitude of individual EGG cycles.

The amplitude envelope of the EGG's was determined by measuring the height of the curves at the rising slope, from the moment when the vocal folds first touch to the moment where the contact area no longer increases (see figure 4A and B). Some authors have established the amplitude of the EGG by measuring the distance between the lowest and the highest point in a cycle (Borden, Baer & Kenney, 1985; Haji, Horiguchi, Baer & Gould, 1986). We feel, however, that our definition is preferable, because the rising slope of the EGG, corresponding to the increase in vocal fold contact area, is more reliably interpreted. In particular the lowest point in the EGG cycle, which is thought to occur somewhere during the open glottis interval, is very difficult to interpret since the actual value of the minimum may strongly depend on artefacts of the measurement situation that have as yet hardly begun to be investigated.

The amplitude envelopes, obtained as described above, were classified as either abrupt or gradual onset. An envelope was categorized as gradual if it contained at least five consecutive pulses with amplitudes more than 10% larger than the preceding pulses (c.f. Figure 4A). All other EGG's were classified as abrupt (c.f. Figure 4B). One may hypothesize

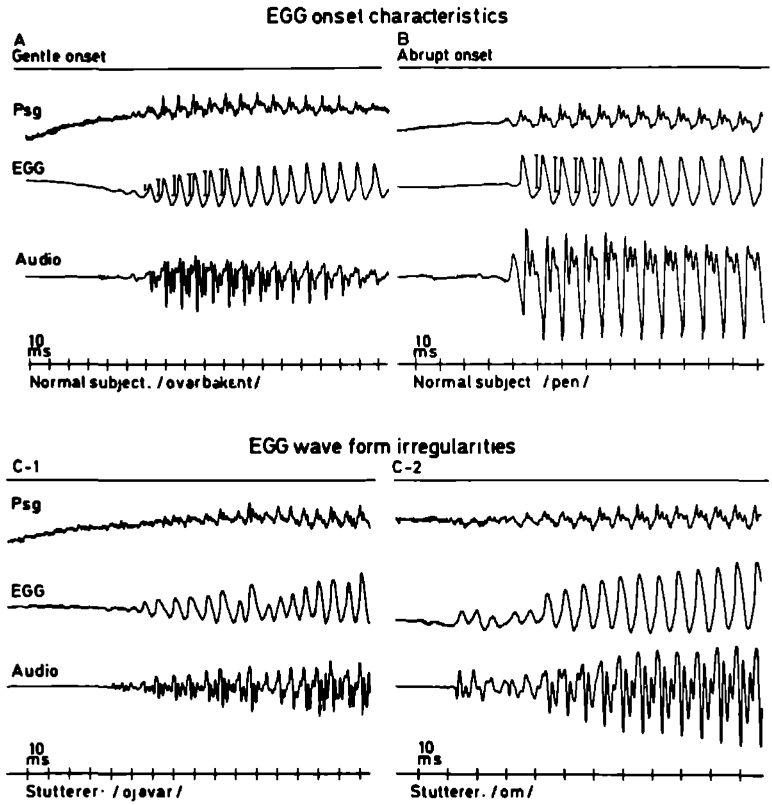

Figure 4: EGG Recordings of gentle and abrupt onset of phonation (A and B) and frequency and amplitude wave from irregularities in fluent speech utterances (C1 and C2). Only the first part of the utterances is shown in the figure.

that the gradual onset in the EGG corresponds with what is known as 'gentle onset of phonation', whereas the abrupt onset seems more likely to be related to a hard attack.

Gross amplitude irregularities were said to be present if one or more of the pulses was more than 15% higher or lower than the neighbouring pulses. In a similar way, gross irregularities in period duration were defined as individual periods with durations that differed by at least 15% from both of its neighbours (see Figure 4 C 1 and 2).

The criteria for classifying the EGG's may seem arbitrary. In a way they are, of course, as are almost all criteria for nominal classification. Yet they more or less presented themselves, in that they represent the lower bounds above which the measurements could be efficiently and reliably made. At the same time, the classification is intuitively appealing. Lower thresholds would have made measurement extremely difficult, since often the measures would have been no larger than the thickness of the lines. Higher thresholds would have resulted in ensembles that seemed very heterogeneous.

Analysis of the speech signals. For technical reasons, only words beginning with a vowel were analyzed. Two kinds of measures were computed: abruptness of the onset of phonation and speech rate. A schematic representation of these measures is shown in Figure 5.

The procedure for determining the abruptness of voice onset is described in detail in Peters, Boves & van Dielen (1986). Of the measures described there only one was computed for the present research, namely the logarithm of the time it takes for the amplitude of the audiosignal to increase from 10% to 90% of its eventual maximum value. This measure was shown to be the best predictor of perceived abruptness of voice onset.

Speech rate was estimated by measuring the duration of the first syllable of the words and by computing the average duration of the syllables. For the monosyllabic words both measures are obviously identical. The measurement was carried out automatically, as an extension of the program that determined the rise time of the amplitude envelope. In order to determine the duration of the first syllable the amplitude envelope was searched for a local minimum corresponding to the syllable boundary. Given the fairly simple phonological structure of the words used, combined with the fact that all polysyllabic words carried the stress on the

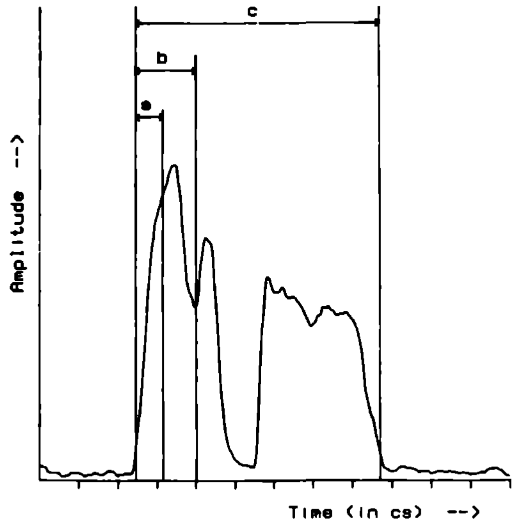

Figure 5: Schematic representation of acoustic measures: a = 10-90% rise time; b = duration first syllable and c = duration of the word, mean syllable duration is computed by dividing the duration by the phonological number of syllables.

first syllable and the fact that all words were pronounced in isolation, it is not surprising that the routine for searching syllable boundaries performed rather reliably. The average duration of the syllables was determined by searching for the start and the end of the words, and dividing that time difference by the number of phonological syllables in the word.

7.3 RESULTS AND DISCUSSION

The experimental data consisted of 7 x 80 = 560 words produced by control subjects and 10 x 80 = 800 words produced by the stutterers. Of the 560 items of the control subjects 7 could not be used in the final analysis, either because of the subject's coughing in the interval between the warning tone and the beginning of the word, or because of the fact that due to some technical problem one of the signals was not properly recorded. One of the stutterers produced only 13 words that were considered as fluent, a second stutterer produced only 21. Because most of the data analysis were based on proportional measures, data from these two subjects was discarded; the addition or deletion of a single extra item, or a different classification of one item, would change the observed proportion of occurence of a given pressure build-up or voice onset type so drastically as to make the available data highly unreliable. The overall design of the experiment (e.g. the counterbalancing of the sub-conditions as well as the situation in which the subjects had to perform their tasks) made it impossible to increase the number of trials until a sufficient number of fluent utterances was obtained. The procedure used to score the words for fluency also prevented us from using the strategy of adding trials until sufficient fluent productions are available. For the remaining stutterers the number of fluent utterances (< 50) was considered high enough to warrant a meaningful analysis of the data. Of the 640 words produced by the remaining eight stutterers 27 were not amenable to analysis due to coughs or failures of the instrumentation. Of the 613 analyzable words 539 were considered as produced in a completely fluent way. These 539 words form the data base for the stutterers.

The relative frequencies of occurrence of the different types of pressure build-up or voice onset were subjected to an analysis of variance. The aim of these analyses was to find out if there are significant differences between the stutterers and the control subjects in the relative frequency with which they use the pressure build-up and voice onset types. Similar analyses were carried out for the acoustic data. However, in the acoustic analysis absolute values for rise time and speech rate were used as the raw data. Relations between the three levels of measurements (pressure build up, EGG, speech) were analyzed with chi-square tests on 2 x 2 and 2 x 3 contingency tables.

In the remainder of this section we will first present and discuss the results of the analyses of the pressure build-up. Next, voice onset types as measured from the EGG will be dealt with. Then, the acoustic measures will be treated. Finally, we will present the results of the contingency analysis. General conclusions will be postponed to the next section.

Subglottal Air Pressure Build-up Types

Because the aerodynamic processes involved in the production of vowels, plosives and fricatives are quite different, separate analyses were carried out for these three classes of word initial sounds. The data are summarized in Table 2.

The vowels /a/ and /o/. From Table 2 it can be seen that the control subjects use a type 1a pressure build-up more often than the stutterers.

Table 2: Mean relative frequency scores of pressure build-up types in fluent utterances in vowels and consonants for normal speakers (N) and stutterers (ST)

Types of pressure build-up	Vowels (/a/ + /O/) A	Vowels (/a/ + /O/) ST	Consonants /p/ N	Consonants /p/ ST	Consonants /s/ N	Consonants /s/ ST
Normal pressure build-up						
Type 1a	89.1	68.9	29.6	18.1	41.4	37.9
Type 1b	6.2	12.7	4.8	7.2	48.6	45.3
Type 1c	1.1	0.9	61.2	37.6	4.6	0.0
Type 1a + 1b + 1c	96.4	81.6	95.6	62.9	94.5	83.2
Deviant pressure build-up						
Type 2	1.1	10.1	0.0	7.6	0.0	1.7
Type 3	1.5	5.9	2.8	7.7	1.4	11.0
Type 4	0.7	0.8	1.6	18.5	2.7	1.4
Type 5	0.0	0.7	0.0	0.0	0.0	0.0
Type 2 + 3 + 4 + 5	3.2	17.1	4.4	32.7	4.1	14.1

This difference is significant ($F(1,13) = 5.26$, $p < 0.05$). The different proportions for types 1b and 1c are not significant. For the total proportions of normal pressure build-up, however, a fairly large difference between the groups can be seen. This difference is statistically significant ($F(1,13) = 6.87$, $p < 0.05$). As might be expected, the fairly large difference between the corresponding proportions, i.e. the summed proportions of occurrence of deviant pressure types, is also significant ($F(1,13) = 7,89$, $p < 0.01$). For the individual deviant pressure build-up types only the data for type 3 are significant. The larger difference for type 2 is not significant, probably due to a large within group variance ($F(1,13) = 2.57$, $p = 0.13$).

The plosive /p/. For the sound /p/ there is a tendency for stutterers to use type 4 at the cost of type 1c, which indicates that stutterers more frequently raise subglottal air pressure to a high level than reduced it before the eventual start of phonation. The difference with normal speakers in these types, however, is not significant ($p = .07$). For /p/ there is a significant difference between the groups only for the total proportions of normal and deviant types of pressure build-up (resp. $F(1,13) = 10.48$, $p < .01$ and $F(1,13) = 7.69$, $p < .02$).

The fricative /s/. For /s/ the between group differences are limited to type 3, ($F\ (1,13) = 7.06$, $p < .05$). Although there is a difference for the totalized proportion of normal and deviant types as in vowels and /p/, this is far from significant.

In general, there appears to be a clear distinction between the groups with respect to the type of pressure build-up. Even in fluent utterances the control subjects use normal pressure build-up types significantly more often than the stutterers. Another way of saying this is that stutterers, even in utterances that are completely fluent from a perceptual point of view, quite often seem to encounter problems in the realization of the physiological processes underlying speech production.

Table 2 does not give data for individual subjects. As described earlier in Peters and Boves (1986) we were not able to detect any systematic patterns in the data for the individuals. Neither could we establish any subgroups within the group of stutterers based on the proportions with which they use specific pressure build-up types. Finally, there appeared to be no relation between the severity of stuttering outside the experiment and the proportion of deviant pressure build-up types used (Kendall's tau = 0.277, $z = -1.127$, $p = .13$).

Electrographic Measurements

The main results of the measurements on and classification of the EGG signals are summarized in Table 3. The data for each type of EGG (i.e., abrupt onset, gentle onset, and presence of amplitude and/or frequency perturbations), were subjected to an analysis of variance with two main factors - group (stutterers vs. controls) and word-initial sound (vowels /a,o/ vs. consonants /p,s/).

The analysis of the abrupt vs. gentle onset showed that both factors were significant: groups $F(1,13) = 10.95$, $p < 0.01$ and word-initial sounds $F(1,13) = 8.0$, $p < 0.01$. As can be seen from Table 3 stutterers use an abrupt voice onset significantly more often than the control subjects. Also, abrupt onsets occur significantly more often in words that start with a consonant than in words beginning with a vowel.

Irregularities in the amplitude and/or the duration of individual periods in the EGG tend to occur more often in the utterances produced by the stutterers. The differences are, however, almost never significant. There is one exception in the case of jitter (irregular period durations)

Table 3: Mean relative frequency scores of the onset of phonation and waveform deviations in EGG in vowels (/a/ + /O/), consonants (/p/ + /s/) and all sounds (/a/ + /O/ + /p/ + /s/) for normal speakers (N) and stutterers (ST)

	Vowels		Consonants		All sounds	
	N	ST	N	ST	N	ST
Onset of phonation						
abrupt	39.7	68.8	68.8	80.0	54.3	72.8
gentle	57.0	30.1	28.6	15.7	42.8	22.9
Waveform deviations						
amplitude	13.3	11.5	13.9	18.9	13.4	16.4
frequency	7.6	12.8	9.5	15.4.	8.6	14.2
amplitude + frequency	5.0	21.7	16.3	26.2	15.6	23.9

in words beginning with a vowel ($F(1,13) = 17.7$, $p < 0.001$).

The analysis of the EGG data leaves one with the impression that the overall voice quality of the control subjects, in the form of voice onset at the one hand and of the absence of jitter and shimmer on the other, is better than the voice quality of the stutterers. Such a conclusion, however, would be premature. Good quality voice is clearly characterized by a low level of jitter and shimmer, but with respect to gentle onset the situation is more complicated. In a recent study, Borden et al. (1985) observed that the amplitude envelope of the EGG showed an abrupt onset, both in the productions of control subjects and in fluent utterances of stutterers. A gradual increase of the EGG's amplitude envelope occured in the fluent utterances only after a number of unsuccessful attempts to produce the utterance. Borden's measurements were confined to the onset of voicing in vowels following the fricative /f/. Therefore, her results should only be compared with our measurements on the words beginning with /p/ and /s/. The words starting with a consonant more frequently appeared to begin with an abrupt onset than words with a word-initial vowel. But in our data, abrupt onsets were found more often in stutterers than in control subjects. Also, a hard voice attack is generally not considered as desirable by speech-language pathologists. Finally, many therapies (e.g Webster, 1980) try to reduce the number of stutters by training the clients to practice a gentle voice onset. These considerations make us take the position that the lower proportion of abrupt onsets in the speech of the controls reflects their overall superior voice quality.

It remains to be explained why our data on abruptness of envelope onset in EGG signals differ from the findings of Borden. We can think of at least two possible explanations. The first, but least probable, is that the discrepancy is due to differences in the measurement and/or classification procedures. The second explanation, which we think is more probable, lies in the different character of the speech task. In our experiment the subjects had to produce 80 words once, and only the fluent productions were analyzed. In Borden's experiment the stutterers were instructed to repeat words until the required number of fluent utterances was obtained. This task is likely to encourage stutterers to use strategies to prevent dysfluencies, and it is well-known that the conscious use of an extremely gradual voice onset may reduce the rate of dysfluencies considerably. In fact, in an experiment related to the present one, Peters and Boves (1986) found that, even after a very short training period, the conscious use of very gradual voice onset reduced the number of stuttered utterances significantly, compared with a normal speaking condition.

Acoustic Measures of Voice Onset and Speech Rate

The results of the measurements carried out on the acoustic speech signals are summarized in Table 4. Analyses of variance on the rise time data and on the two rate measures showed that the differences between the group means are nowhere near significant. Therefore, it must be concluded that from a purely acoustic point of view the fluent utterances of stutterers cannot be discriminated from utterances produced by control speakers. This is, of course, not really surprising, given the strict criteria an utterance had to fulfill in order to be considered fluent.

It should be obvious, however, that the failure to find significant differences between the groups in the acoustic domain is quite contrary to what has been reported for the physiological signals. The single most conspicuous discrepancy concerns the voice onset measure obtained from the EGG and its acoustic counterpart. The only explanation for this discrepancy is the obvious one - the amplitude of the EGG is not a direct measure of the energy with which the vocal tract is excited. There are a number of reasons why EGG amplitude is not a direct representation of the acoustic energy radiated at the lips. First of all, it may take a few

Table 4: Mean scores of rise time, duration first syllable ad mean syllable time in ms in speech utterances with initial /a/ and /o/ for normal subjects (N) and stutterers ST)

Acoustical Measurements	N	ST
Rise time	70.1	71.2
Duration first syllable	284.5	303.6
Mean syllable duration	202.0	322.4

cycles before the resonances of the vocal tract have fully developed, the more so if the tract's configuration changes quickly, as may be the case during the transition into the first vowel of a word. Secondly, the discrepancy between EGG and acoustic rise time may be the result of different strategies in speech production in stutterers and normal speakers. The increase of acoustic amplitude (section a of Figure 4) is strongly influenced by the opening of the mandible and the consequently increasingly large area of the orifice at the lips. Stutterers might have learned to open their mouth slowly at the beginning of a word-initial vowel to slow the acoustic rise time that would otherwise occur too rapidly as a result of the abrupt glottal closure. Or, they may have learned to close the glottis abruptly in order to increase the acoustic rise time that would otherwise occur too slowly as the result of a slowly moving mandible. Thirdly, the amplitude of the time derivative of the EGG may be a better indicator of the strength of the excitation, because it seems to be a better representation of the rate of changes of air flow than the eventual absolute value of the area of contact between the vocal folds. Finally, the duty cycle of the glottal pulses, and perhaps also their amplitude, may change during the first few periods. These hypothetical explanations remain to be tested. These tests are planned for the near future.

Relationship between Pressure Build-up and Onset of Phonation

It is interesting to know if deviant pressure build-up is related either to abrupt or gentle voice onset (as determined from the EGG or the acoustic signal) or to irregularities in the amplitude or period duration of the glottal pulses as seen in the EGG. To see if there were such relationships chi-square tests were performed on a number of 2 x 2 contingency tables, both for individual subjects (for whom the absolute frequencies allowed for meaningful tests) and for groups of subjects. None of these chi-square tests approached significance. This result strongly suggests that the respiratory manoeuvres involved in the control of subglottal pressure and the laryngeal manoeuvres that initiate and maintain vocal fold vibration are to a large extent independent processes. There is, of course, some dependence. Phonation cannot start unless subglottal pressure has exceeded a minimum threshold and, in the absence of a complete closure in the vocal tract, the pressure cannot start to rise before the glottis is closed. But apart from these common boundary conditions the processes seem independent. This finding suggests that it may be unwise to extrapolate or generalize results from one process to another.

One of the criteria for classifying pressure build-up patterns is the time span between the start of phonation and the moment when the pressure maximum is reached. Three categories can, in fact, be discerned: type 1a, where phonation starts on the rising slope of the pressure curve, type 1b, where phonation commences at the moment when the pressure maximum is reached, and type 2, where phonation starts only well after the moment when the pressure maximum is attained. Using the three categories just explained and the two classes (abrupt vs. gentle) of voice onset obtained from the EGG, 3 x 2 contingency tables were constructed. In the group of stutterers a chi-square test showed a very significant tendency for voice onset to become more abrupt if the start of phonation is shifted relative to the pressure maximum (chi-square = 28.22, df = 2, $p < 0.001$). It seems sensible to hypothesize that this relationship is an effect of the coordination of respiratory maneuvres and laryngeal adjustment. The exact nature of this interdependence remains, however, to be investigated. Model simulations like Ishizaka and Flanagan (1972) and Titze and Talkin (1979) might lend considerable insight into the physiological limits of the interplay of subglottal pressure build-up and muscular adjustments in the larynx.

7.4 CONCLUSIONS

From the work reported in this paper a number of conclusions can be drawn. The first and probably most important conclusion is that there is ample reason to doubt that the perceptually fluent utterances of stutterers are indeed fluent on all levels of speech production. From the data on subglottal pressure build-up it is obvious that the group of stutterers differs significantly from the control group with respect to the occurence of deviant build-up types. It must be stressed that this significant difference was found even when the criteria for fluency were very strict. That the criteria were strict is borne out by the fact that none of the acoustic measures even tended towards significant differences between the groups. Thus the physiologic processes associated with or underlying utterances that seem to be completely fluent on the acoustic level contain considerable deviance, that might be called subclinical or physiological stutters. This finding, which corroborates previous observations of Freeman (1984) and Watson and Alfonso (1982) calls into question the outcomes of many other experiments in which perceptually fluent utterances of stutterers were analyzed. This was also concluded by Adams and Runyan (1981) and Starkweather (1982) on the base of their critical review of the pertinent literature. It may well be that a considerable proportion of these allegedly fluent utterances should rather have been considered as physiological stutters, that should have been analyzed separately from the really fluent utterances. Such a separate reanalysis of completely fluent and physiologically dysfluent utterances might lead to much more homogeneous pictures of the stuttering behavior.

The second conclusion drawn from the results of this investigation is somewhat related to the first. We observed that the abruptness of voice onset, as determined from the EGG, is significantly higher in stutterers than in nonstutterers. If one is willing to assume that an abrupt rise in the amplitude of the EGG is related to a higher degree of muscular tension in the laryngeal region, this finding seems to confirm previous observations that the physiological processes underlying speech production in stutterers are close to the limits within which the articulatory systems works smoothly and without disturbance. We realize that on this point our findings are contrary to the results of Borden, Baer and Kenney (1985), but these discrepancies can be explained largely by the difference in the design of the two experiments. This points to yet another relation between the first and second conclusion. It becomes increasingly clear that the outcomes of many experiments on stuttering are to a very large extent determined by the details of their design. Generalization of results to other experiments or, for that matter, to real life situations, should only be attempted on the basis of a comprehensive model of the physiology and acoustics of speech production.

The third conclusion drawn from the results of our experiments is that the various levels in the process of speech production seem to be fairly independent. Knowledge about the functioning of the respiratory system in the production of an utterance does not help in predicting the way in which the articulatory systems perform, nor does knowledge of either respiratory or articulatory functioning suffice to predict the character of the acoustic speech output. This finding warns against extrapolating from one level of speech production to another. It also emphasizes the need of a comprehensive model, incorporating all relevant levels of speech production, including the cognitive and emotional levels.

The conclusion that the levels of speech production seem to be fairly independent must, of course, be qualified. The various levels do interact and they may define each other's boundary conditions. If, for instance, the subglottal pressure is too high for comfortable phonation, vocal fold vibration is likely to be postponed until the pressure has dropped to a level within the range for normal phonation. Also there is a clear tendency for the onset of the EGG envelope to be more abrupt if the onset of phonation is delayed with respect to the moment when subglottal pressure reaches its maximum value. Again, these findings underline the need of a comprehensive model in which they can be given a place and which will serve as a framework for their interpretation.

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CHAPTER 8

PROGRAMMING AND INITIATION OF FLUENT SPEECH UTTERANCES IN STUTTERING

Herman F.M. Peters

and

Wouter Hulstijn

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8.1 INTRODUCTION

Historically stuttering has frequently been linked to the discoordination of activity between and within the subsystems of the speech mechanism (Van Riper, 1982). A number of discoordination theories are formulated: stuttering is a disruption of coordinated muscle activity in the laryngeal system (Adams, 1984), an incoordinated timing of articulatory movements (Zimmermann, 1980), a disruption in coordination or timing between laryngeal, respiratory and articulatory system (Adams, 1974; Kent, 1984; Van Riper, 1971; Wingate, 1976). All these theories share a common hypothesis which suggest that stutterers have greater difficulty than non-stutterers in initiating and controlling speech movements.

Stutterers' ability to initiate phonatory and articulatory movements has been investigated in numerous reaction time studies using the laryngeal reaction time (RT) paradigm. While the respiratory and articulatory activity is controlled by specifying the phonetic characteristics of the response, stutterers' ability to initiate and terminate voicing rapidly in response to external response signals is investigated. The required response in speech RT studies may be an isolated vowel, a single word or a short phrase. In RT studies on the initiation of single, speechlike, vowel productions a number of studies report significant differences between stutterers and non-stutterers (Adams & Hayden, 1975; Cross & Luper, 1979; 1983; Cross, Shadden & Luper, 1979; Hayden, Adams & Jordahl, 1982; Horii, 1984; Starkweather, Franklin & Smigo, 1984), others do not report these differences (Murphy & Baumgartner, 1981; Venkatagiri, 1981; Watson & Alfonso, 1982). The limitation of single vowel production, however, may be that it is insufficiently speechlike to represent communicative speech. In RT studies on the production of syllables or words, stutterers are unequivocally slower in speech initiation (Borden, 1983; Hand & Haynes, 1983; Hayden, Adams & Jordahl, 1982; Healy & Gutkin, 1984; McFarlane & Prins, 1978; Prosek, Montgomery & Walden, 1979; Reich, Till & Goldsmith, 1981; Starkweather, Hirschman & Tannenbaum, 1976; Till, Reich, Dickey & Seiber, 1983; Watson & Alfonso, 1982).

Generally, differences between stutterers and nonstutterers seem to be greater the more speechlike the subjects' response is. Also the subjects' reaction times are much longer in RT studies with syllable or word production in comparison with single vowel response RT studies. Therefore, either motoric or linguistic parameters may be of influence on the ultimate speed in initiating and terminating voicing. However, no systematic research has been done on the effect of these response characteristics on speech reaction times. The studies of Reich et al. (1981), Till et al. (1981) and Watson & Alfonso (1982) suggest as one possibility that the speech reaction time differs on the basis of motoric complexity. If that possibility is correct longer reaction times may have resulted either from a longer programming process or a longer initiation phase. By "programming" we refer to those neuromotor activities that lead to the formulation of muscle commands. By the "initiation phase" we refer to the necessary physiological activities, such as contracting the respiratory muscles to build up subglottal pressure or flexing the laryngeal muscles to adjust glottal resistance, which have to be realized just before the onset of speech.

Apart from the separation between programming and initiation a number of authors conclude that fluent and dysfluent utterances in stutterers are characterized by difficulties in (1) the initiation of voicing (Conture, Schwartz & Brewer, 1985; Freeman & Ushijima, 1978; Peters & Boves, 1986), (2) the coordinative timing of articulatory movements (Zimmermann, 1980a) or (3) difficulties in the timing and sequencing of the respiratory, phonatory and articulatory systems (Adams, 1974; Ford & Luper, 1975; Janssen, Wieneke & Vaane, 1983; Yoshioka & Löfqvist, 1981). These findings support the idea that stuttering behaviors may be characterized by an imperfect operating of the peripheral speech mechanisms or a discoordination between the different subsystems involved in speech production.

However, if stuttering is described as a disorder of movement it can be conceived also as a possible disorder in the advance preparation or programming of speech motor activity, particularly since most disfluencies occur at the onset of words of phrases. As Zimmermann has concluded (1980b) timing disturbances may result from malfunction of the motor programming system in general. In the area of motor control it is a widely shared idea that a detailed representation of all or at least the first part of the movement sequence is prepared in advance of the movement itself. It is assumed that programming or advance preparation of the utterance completely precedes the execution itself (Monsell and Sternberg, 1981; Sternberg et al., 1978) or runs more or less in parallel with the execution process (Gracco, 1986; Hulstijn, 1987; Hulstijn & van Galen, 1983; Keele, 1981; Schmidt, 1982, 1983). According to the last authors this programming process involves a limited number of successive processes: first, there is an abstract representation of the type and sequence of movements taken from memory and placed in a kind of buffer; secondly, additional parameters, (speed, size, force, accuracy and timing of the movement) are supplied; and finally the program is translated into actual muscle commands before the initiation of physical movements. It may be obvious that an increase in motor complexity may be attended by a longer programming process. According to Keele (1981) this motor complexity is directly proportional to the number of muscle groups or physiological subsystems involved in the movement. In addition, a more powerful determiner of motor complexity is the number of elements in the movement; an increasing number of elements results in a longer reaction time (Van Galen & Wing, 1984).

Within a reaction-time paradigm simultaneous recording of responses in the laryngeal, articulatory and acoustic domain could give a clearer idea of the programming and initiation of physiological processes and the onset of speech. Lengthened latency times (see Table 1) might result from programming difficulties, if any, while lenghtened initiation times might give insight into initiation problems of a specific response system (for instance discoordination among intrinsic laryngeal muscles v. discoordination in oral movements) or problems in the coordination of the different subsystems involved (for instance the coordination of laryngeal movements with articulation and respiration).

As may be seen from Table 1, within reaction time research a wide range in terminology is used to indicate the successive intervals between the response signal and the onset of speech. In this study the interval between the response signal and the start of peripheral physiological processes before the onset of speech is called the latency time, while the interval between the start of physiological activity and the onset of speech is called the initiation time. In the actual experiments the precise determination of the moment at which the physiological activity starts obviously depends on the subsystems that are measured, on the recording techniques that are used and on the first phoneme that has to be spoken. In the present study the start of laryngeal EMG-activity is used to divide the speech reaction time into latency and initiation. This

Table 1: Schematic representation of the terminology in reaction time research

	Response signal	First manifestation in EMG	Onset of speech
	No peripheral processes	physiological processes	acoustic output
Motor models Schmidt (1982)	response time		
	reaction time		
	premotor reaction time (in advance preparation)	motor reaction time	movement time
Acoustic RT research Adams (1982)	voice initiation time		
	phonetory reaction time		
	laryngeal reaction time		
Physiological research Watson/Aldonso (1983)	initiation time		
	neuromotor process	initiation process	
Borden (1983)	initiation time		
	premotor planning	motor initiation	execution
Shipp et al (1984)	vocal reaction time		
	neural time	mechanical time	
Peters/Hulstijn(this study)	speech reaction time		
	latency time	initiation time	

choise, however, mainly was made more for reasons of clearity and intelligibility of the data presentation than based on theoretical arguments.

The aim of the present study is to investigate whether longer acoustic reaction times in the fluent speech utterances of stutterers may result from a programming deficit or whether they are caused by a disturbance in motor initiation. It was assumed that motoric planning or programming consumes more time if an utterance of increasing length has to be centrally organized. Therefore the length of speech utterances was systematically varied between one-syllable words, polysyllabic words and sentences. If stutterers encounter problems in the programming stage it would be predicted that the difference between stutterers and nonstutterers would be larger in more lengthy and more complex utterances. Another way to test a possible deficit in motor planning or programming may be the use of different tasks. In a task in which part or all of the programming could be done before the response signal (a delayed reading task) it could be hypothesized that the difference between the groups in reaction time would decrease, but in a task in which there is no time for preparatory programming of the utterance (an immediate reading task), a relatively larger difference in reaction time could be expected between stutterers and nonstutterers.

A second approach, used in this study, is to explore the effects of the experimental variables on the various intervals in which the speech reaction time can be separated. The division in latency and initiation time has been mentioned already, but in this study each of these intervals is further subdivided. It might be assumed that utterance length and type of reading task mainly influence the initial latency parts of the reaction time, but it will be interesting to investigate whether this holds also for the difference between stutterers and nonstutterers.

Therefore, in this study the intervals between a number of relevant points were measured: (1) the start of laryngeal muscle activity, (2) the initial vocal fold closure for subglottal pressure build-up, and (3) the start of supralaryngeal articulation. These points can be reliably located with the use of certain physiological measures. Accordingly, in this study EMG was used to record the activity of extrinsic laryngeal muscles and lip muscles, and EGG was used to record the movements of the vocal folds. EGG has the advantage of being completely noninvasive and it does not impede normal speech production.

In addition to simply measuring these intervals, one may ask how they would be influenced by varying the speed with which the subjects have to react. Increasing the timing demands by requiring very fast reactions will result in more stuttering and probably in a disorganisation of the various physiological processes that occur in the onset of speech. The question can be raised whether speed affects all intervals equally, or whether its effect is localized to a few intervals. Furthermore it will be investigated which of the intervals demonstrate most clearly the problems that stutterers have in a speed condition. Speed was varied by presenting both tasks in two speed conditions: a normal reaction time condition and a reaction time condition in which fast responding was forcefully elicited by means of additional instructions and visual feedback about reaction times.

A final question concerns the subgrouping of stutterers. It is well known that stuttering behavior is highly variable. One reason may be that different subgroups of stutterers respond in a specific way. Borden

(1983) has reported differences between severe and moderate stutterers in "initiation" and "execution" times. Similarly Watson and Alfonso (1982, 1983) reported differences between severe and mild stutterers in the length of the foreperiod of acoustic reaction time. Therefore, the total group of stutterers was divided into subgroups (very mild, moderate and severe stutterers) in order to investigate whether the effect of the experimental variables differs among these subgroups.

8.2 METHODS

Subjects

Twenty adult male stutterers between 19 and 28 years and twenty nonstutterers, matched for age within one year, participated in the experiment. None of the stutterers had been enrolled in any kind of therapy during the two years preceding experiment. All subjects had normal hearing acuity and normal language and voice quality.

Stuttering severity was classified on the basis of the following clinical analysis. A certified Speech-Language Pathologist subjectively rated severity of stuttering during conversational speech and during the reading of a standard passage on three seperate measures. The percentage of dysfluency, the level of overt muscle tension of the dysfluencies and the frequency of nonverbal stuttering behavior were rated on a three-point scale. The mean score of these scaling values in both speech conditions was used to classify the stutterers into three subgroups: very mild stutterers (5 subjects), moderate stutterers (9 subjects) and severe stutterers (6 subjects). For a more detailed description of this classification system the reader should see Peters & Boves (1986).

Design and Procedure

Design. Each subject was measured in two conditions - normal and time-stressed. Each condition contained two tasks - delayed and immediate presentation. In each of these 4 (2x2) blocks, there were 60 trials within which the length of utterance and the initial sound were varied. The details of the conditions, tasks, trials, and stimulus words are presented below.

Tasks and conditions. The experiment followed a reaction-time paradigm with two tasks. In the first task the stimulus-word or sentence was presented for the subject to read followed by a pause before presentation of the signal to respond (delayed reading task). In the second the subject was required to respond immediately after presentation of the stimulus (immediate reading task).

In the delayed reading task a 100 Hz tone of 200 msec duration was presented auditorily to the subject while at the same moment the stimulus word was displayed on a TV monitor during a period of three seconds. The auditory warning signal indicated that after a variable foreperiod of 1 to 3 seconds an auditory (1000 Hz tone lasting 100 msec) and a visual response signal (a row of asterisks displayed on the screen) should follow. The variable foreperiod served to prevent the subjects from adopting a routine. Subjects were instructed to read the word or sentence on the monitor as soon as possible after the simultaneous presentation of the auditory and visual response signal.

In the immediate reading task the procedure was nearly the same with the only difference being that at the same time as the auditory warning signal a row of asterisks was displayed on the screen. The start of the presentation of the stimulus word coincided with the start of a 1000 Hz tone lasting 100 msec, which served as the response signal. The subject was instructed to read the word as soon as possible after the presentation of the response signal.

All subjects were given 10 training sequences in each task before the start of the experiment. Moreover, in each experimental task five practice trials preceded the 60 test stimuli. The subjects were instructed to make no speech movements before the onset of the response signal.

The delayed and immediate tasks were both presented in two speed conditions: a normal reaction time condition and a time-stress condition in which fast responding was requested. In the normal reaction time condition the subject was instructed to read the stimulus words as soon as possible after the response signal. In the time-stress condition the subjects received feedback on their reaction times, as measured by a Voice Key displayed on the TV screen. In addition the experimenter stressed the importance of responding quickly several times during the first practice trials. Both tasks and both speed conditions were presented in a randomized order.

There were in fact three additional conditions for which the results form a separate study to be presented in a separate article. All five conditions were randomized in a Latin square design so that order effects were controlled in the two conditions reported here.

Stimulus words. In each of the two tasks 60 trials were presented i.e. 20 one-syllable words, 20 polysyllabic words and 20 sentences of about 10 syllables each. The one-syllable words were of the type VC and CVC. The polysyllabic words contained three or four syllables with stress on the first syllable. These words contained one or two consonant clusters of at most three consonants each. The sentences started with the same type of polysyllabic words so that the three stimulus categories could be compared. Within each condition, the identical words and sentences were used in each task, but to avoid a practice effect from one condition to another, different words and sentences were used in the two conditions. The different words and sentences were matched for initial sound and for utterance complexity. Utterance complexity was determined by asking a panel of two independent judges to match each block of five words for subjective utterance complexity, considering number of syllables and the complexity of specific consonant clusters.

Peters, Boves and Cox (1984) described large differences in the acoustical characteristics of abruptness of voice onset for different speech sounds. To control for this variability, it would have been desirable to use only one initial speech sound. But, in order to prevent the possibility of preparation in the reaction time paradigm, at least four different sounds had to be used. In addition, the physiological differences in producing different sounds could be expected to influence the reaction time because of differing demands on coordination and movement.

Consequently two contrasted vowels /a/ - low, back, unrounded - and /o/ - high, back, rounded - and two contrasted consonants /s/ - unrounded, fricative - and /p/ - rounded, plosive - were chosen as initial sounds. For each of the four initial sounds and for each of the three utterance lengths there were 5 trials, making a total of 60 trials for each task. In addition, the experimental trials were preceded by five practice trials. Because not enough one-syllable words existed for each of the experimental conditions a few nonsense words were introduced. Because of the severe constraints on the selection of stimulus words on the one hand and the finite number of words in the language, it was not possible to control for word frequency effects, even though it might be expected that words of greater frequency would be more easily (quickly) produced.

Speech Characteristics

Fluency criteria. For this study only those speech utterances judged to have been spoken fluently were analyzed. In order to be accepted as fluent an utterance had to satisfy two criteria. First, there were no visual signs of struggle in the facial or body movements of the subject directly before or during the production of the token. The experimenter noted these visual signs of dysfluency during the recording session. Secondly, the utterance should not contain audible hesitations, prolongations or repetitions. These acoustic signs of dysfluency were judged from an audio-recording of the subjects' speech by two trained raters. All stimuli on which the judges disagreed were treated in an additional rating session. In this session the two raters discussed their original ratings until they reached a consensus on all stimuli. The majority of items on which the raters disagreed were readily recognized as containing dysfluencies that were missed by one of the raters during the first session. In general this procedure guaranteed that virtually no dysfluent item were allowed to pass as if it was fluent.

Perceptual judgment of speech quality. The instruction to respond as quickly as possible could easily influence speech quality during the speech tasks. Therefore, a perceptual judgment experiment was carried out on speech samples from both speed conditions according to the procedure described by Boves (1983) and Franken (1987).

Recorded speech samples from both speed conditions of 10 stutterers and 10 nonstutterers were perceptually judged by 25 raters on six 7-point rating scales. The 10 speakers were selected from the total of 20 by the availability of at least three fluent sentences with initial /a/ and /o/ in both speed conditions. These six sentences were the necessary minimum to construct a speech sample from each subject large enough for the judges to rate with the scales given below. The selection of the rating-scales was based on variations in speech quality that could be expected as the result of different instructions in the two speed conditions and on observations made during the experiment. The 7-point rating scales used were:

1. slow - fast
2. unnatural - natural
3. monotonous - with inflection
4. quiet - loud
5. unclear - clear articulation
6. toneless - clear voice

Instrumentation

A schematic diagram of the instrumentation used in the experiment is shown in Figure 1. During the experiment the subject was seated in the experimentation room in front of a TV monitor in the presence of the experimenter. Technical and electronic equipment for the recording of physiological measurements was located in a second room and operated by a technician.

An Apple II+ microcomputer generated the stimuli and controlled the experimental process in real time. A randomization program generated a variable foreperiod of 1000, 2000 or 3000 msec after an auditory warning signal followed by the response signal. After a period of three seconds the stimulus word disappeared from the TV screen. The subject was instructed to stop responding after these three seconds, even though he might not be finished. This procedure was followed to produce a stable baseline of no responding against which the subsequent response could be measured. A variable interval of 3, 4 or 5 seconds followed before the next test sequence was started.

Speech production was measured by simultaneous recordings in the laryngeal, articulatory and acoustic domain. To determine the initiation

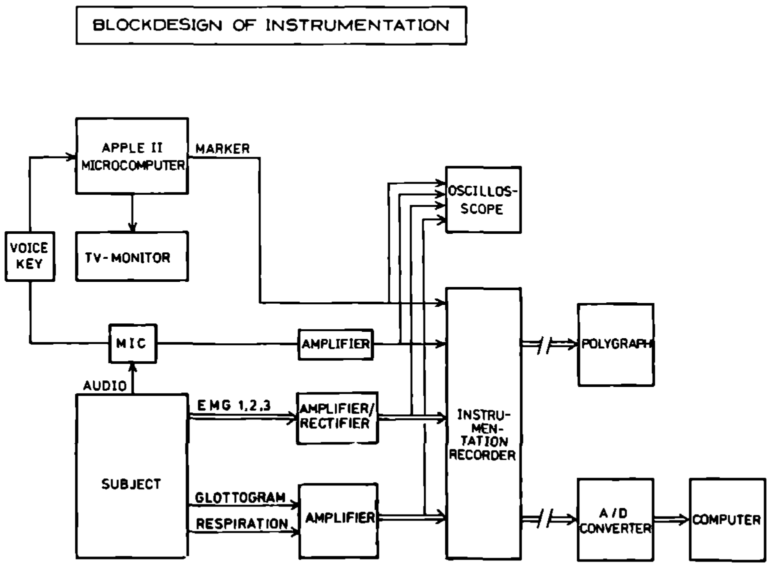

Figure 6: Schematic representation of the experimental set-up during the experiment.

of laryngeal and articulatory muscle activity, surface electromyographic (EMG) measurements were taken from the laryngeal area and from the lips. Surface EMG activity in the laryngeal area was recorded by means of Beckman miniature surface Ag/AgC1 electrodes. These electrodes were placed 3 cm lateral to and equidistant from the midline on the thyroid lamina at the level of the thyroid notch. EMG activity of the orbicularis oris inferior was recorded by silverball electrodes of a type ordinarily used in electro-cochleography (San-ei Sokki, Inc.). These spherical electrodes have a diameter of only 0.4 mm and are attached with flexible tape on the lip. In this way oral movements were not hindered in any way during speech production. The electrodes were connected to differential preamplifiers (Honeywell, EMG preamplifier). Signals from the preamplifiers were fed to amplifiers (Honeywell, Accudata 135) adjusted with the low-frequency filter at 50 Hz and the high-frequency filter at 500 Hz. Each EMG recording was calibrated using an external calibrator set at 200 uV. Analog EMG signals were rectified and integrated with a time constant of 40 msec.

Vocal fold movements were recorded using a Fourcin Laryngograph (Fourcin, 1981). A pair of gold plated circular electrodes were placed on the subject's skin, equidistant from the median on both sides of the thyroid cartilage. The electrodes were held in place by means of an elastic band around the subject's neck.

The speech signal was recorded using a condenser microphone (AKG, type 451 E) placed in front of the subject's mouth at a distance of approximately 30 cm.

All signals including the warning and response signals were recorded on an FM recorder (Philips Analog 14) for subsequent processing. To obtain acceptable signal quality in acoustical analysis the subject's speech was also tape-recorded (Revox A 70 audio recorder).

In connection with another experiment two mercury strain gauges were placed on the subject's thorax. In our judgment these gauges could not have influenced the subject's responses.

Data analysis

Computerized data processing and analysis was performed on the EMG measurements. Speech reaction time and EGG reaction time and initiation time were calculated from paper recordings made afterwards with a

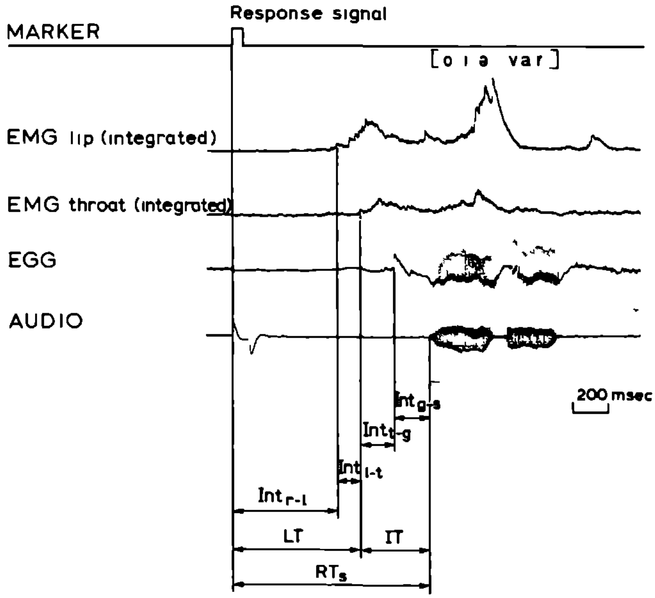

Figure 2: Schematic representation of the calculated interval measures: RT_s = speech reaction time, LT = latency time (= throat EMG reaction time), IT = initiation time (= the interval between the start of throat EMG activity and the onset of speech), Int_{r-l} = the interval between the response signal and lip reaction time (RT_l), Int_{l-t} = the interval between start of throat EMG activity and initial glottal closure, Int_{t-g} = the interval between the start of throat EMG activity and initial glottal closure and Int_{g-s} = the interval between initial glottal closure and onset of speech.

polygraph (Elema-Schonander Mingograph), running at 50 mm/sec. and high frequency cut-off of 700 Hz.

The analysis of variance followed a repeated measures design with the differences between the two groups as the between-subjects variable, and the speech conditions, the tasks, the utterance lengths, and the initial sounds as the four within-subject variables.

Measurements made and calculated from the recordings are schematically shown in figure 2. The following interval measurements are calculated.

1. The speech reaction time (RT_s): the time between the start of the response signal and the onset of speech,
2. The latency time (LT) = EMG reaction time at the throat: the interval between the response signal and the initiation of EMG-activity at the throat,
3. The initiation time (IT) = the interval between the start of the throat EMG activity and the onset of speech,

4. EMG reaction time lip (Int_{r-l}): the interval between the response signal and the initiation of EMG activity at the orbicular oris inferior,
5. The interval between the start of lip EMG activity and the start of throat EMG activity (Int_{l-t}),
6. The interval between the start of throat EMG activity and the first rapid oscillation in EGG which represents the initial glottal closure (Int_{t-g}),
7. The interval between initial closing of the vocal folds and the onset of speech (Int_{g-s}).

The experimental data were produced by 20 stutterers, and 20 control subjects. The frequency analysis of dysfluencies was carried out on all the 20 stutterers. Analysis of the reaction time data was carried out on the fluent speech utterances. For each of the 12 stimulus categories in each task (4 initial sounds x 3 lengths) the reaction time data were averaged over 5 (respectively 4, 3, 2, 1) fluent utterances. In a number of subjects there were no fluent utterances in some stimulus categories. The overall design of the experiment (i.e. the counterbalancing of the subconditions as well as the real time process control during the experiment) made it impossible to increase the number of fluent trials until a sufficient number of fluent utterances was obtained.

In subjects with no fluent utterances in less than 10% of the stimulus categories the missing data were interpolated on the basis of the scores of comparable stimulus categories. This was done in only 12 stimulus categories out of a total of 768 stimulus categories (12 x 2 x 2 x 16 subjects). In 4 subjects there were no fluent utterances in 10% or more of the 48 (12 x 2 x 2) stimulus categories. Therefore, the data from these four subjects were discarded. Because of this limitation in the number of stuttering subjects a data analysis on subgroups of stutterers for all stimuli would be precarious. In the one-syllable stimulus categories, however, all subjects produced one or more fluent utterances. Therefore it was decided to carry on the data analysis on the subgroup scores with respect only to the one-syllable stimulus categories.

Frequency of dysfluency

Before describing the reaction time data, the effect of the experimental variables on stuttering frequency will be discussed. To this end the frequency of stuttering was separately analyzed for the dysfluencies that occur on the initial sound of the utterance (initial dysfluencies) and the dysfluencies that are produced in the remaining part of the utterance (following dysfluencies) for all 20 stutterers. The 16 stutterers who remained for reaction time data analysis produced about the same picture, but their stuttering frequency was in general much lower because four stutterers which had been discarded included two very severe stutterers.

Figure 3 depicts the main results. This figure displays the percentage of initial dysfluencies that were stuttered on each of the three stimulus lengths in the two speed conditions. Obviously the frequency of the following dysfluencies is a direct function of the number of syllables in the utterance. Therefore these following dysfluencies are presented as a percentage of the total number of syllables in the utterances that were spoken.

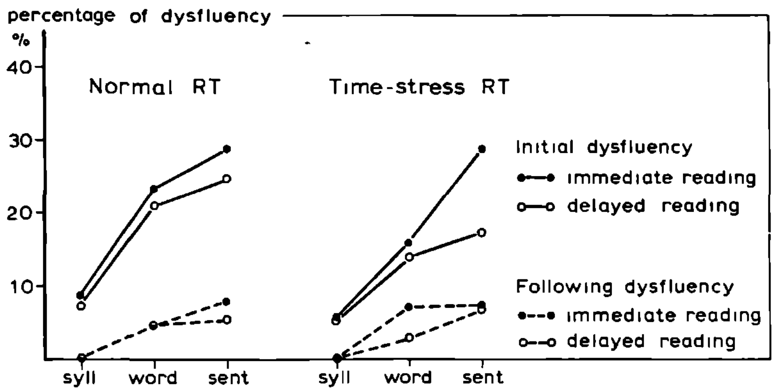

Figure 3: Stutterers' dysfluency in the normal reaction time condition (normal RT) and the time-stress reaction time condition (time-stress RT) for all stutterers (n=20).

It is quite clear that initial speech sounds elicit a much higher percentage of stuttering than the following syllables of the same utterance. A second effect, which is also quite marked is the effect of utterance length ($F(2,38) = 7.73$, $p < .01$): in both speed conditions and both task conditions the percentage of initial dysfluencies on polysyllabic words was more than twice as high as on one-syllable words and also much higher at the beginning of sentences than on polysyllabic words. The task effect was clearly much smaller, but still significant ($F(1,19) = 7.60$, $p < .05$), i.e. in the delayed reading task in which the reading, posturing and necessary programming processes can be done during the foreperiod, the percentage of initial dysfluencies was lower. As is clear from Figure 3, in longer utterances the task effect is much larger, resulting in a significant interaction between task and utterance length ($F(2,38) = 4.02$, $p < .05$). The effect of speed was quite unexpected. In the time-stress RT condition the frequency of dysfluency was lower (by 4.7%) than in the normal RT condition, but this effect dit not quite reach significance ($F(1,19) = 4.07$, $p = .055$). However, as will be discussed later, speech behavior in the time-stress condition was less clearly articulated and showed reduced intonation contours. The last effect to be analyzed was the influence of the initial speech sound. The percentage of initial dysfluencies on "p" was slightly higher, resulting in a significant sound effect ($F(3,57) = 3.33$, $p < .05$). The interactions were not significant.

The percentage of following dysfluencies did not differ between both speed conditions. However, there was a significant task effect ($F(1,19) = 6.50$, $p < .05$). As shown in Figure 3 this task effect occurs only for words in the normal RT condition and for sentences only in the time-stress condition. This results in a higher speed x task x length interaction which was statistically significant ($F(2,38) = 13.41$, $p < .001$), but difficult to interpret.

Intervals within the speech reaction time and the effect of initial speech sound.

One of the questions in this study is whether longer acoustic reaction times in stutterers are demonstrated primarily in the interval between the response signal and the onset of physiological processes or in the later intervals between the onset of physiological activities and the onset of speech. To answer this question the differences between stutterers and nonstutterers in the various intervals (see Figure 2) are displayed in Figure 4. To compare the group effect for latency time with that for initiation time, speech reaction time was subdivided into two

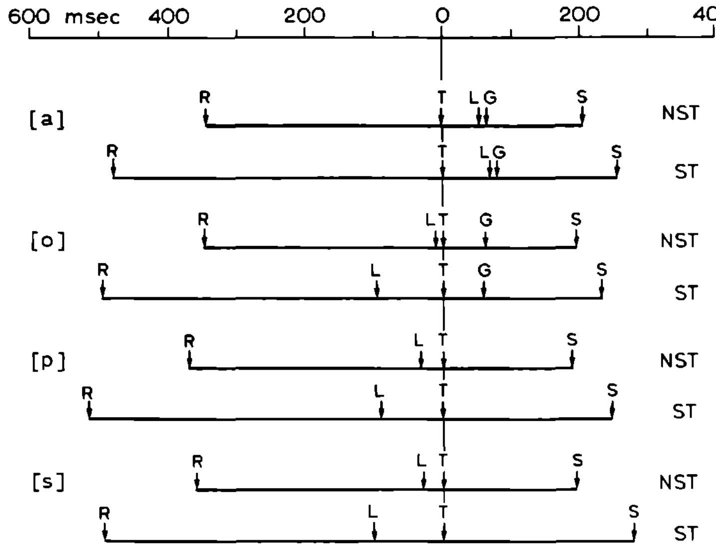

Figure 4: Timing of laryngeal and articulatory movements between the response signal (R) and the onset of speech (S) in fluent utterances with initial /a/, /o/, /p/ and /s/ (T = start of throat EMG activity, L = start of lip EMG activity and G = initial glottal closure) for stutterers (ST) and nonstutterers (NST). The data are aligned so that the zero (no time) line is at the start of throat EMG activity.

parts in relation to the start of throat EMG activity. The start of throat EMG activity (T) was chosen as the line-up point because lip EMG activity in /a/ is not required and, compared with /o/, /p/ and /s/ produces deviant intervals. Because of differences between the initial sounds (/a/, /o/, /p/ and /s/) in the duration of the various intervals, the mean intervals for each of the groups are presented separately for each sound.

Effects of initial sound. As shown in Figure 4 the lip EMG activity in utterances with initial /a/ starts after throat EMG activity. This is the opposite of utterances with initial /o/, /p/ and /s/ in which lip movements start first. Because of the subordinate role of lip movement in /a/ lip reaction time was analyzed only on utterances with initial /o/, /p/ and /s/. In /p/ and /s/ phonation starts from an open glottis position and consequently no initial closing of vocal folds can be derived from the signal. So, for these two sounds Figure 4 shows no intervals between the start of throat EMG activity and the onset of speech and the data analysis on Int_{t-g} and Int_{g-s} was performed only on /a/ and /o/.

The results of the analyses of variance for the main effect of initial sound are given in Table 2. In this and the following tables first the results for the total speech reaction time (RT_s) are presented and than this period is separated into the latency time (LT = the interval between the response signal and the start of throat EMG activity) and the initiation time (IT = the interval between the start of throat EMG activity and the onset of speech). Subsequently the latency time is subdivided into the intervals Int_{r-l} and Int_{l-t} (see Figure 2) while the initiation time is subdivided into Int_{t-g} and Int_{g-t}.

Table 2: Summary of the main effects of initial sound (/a/, /o/, /p/ and /s/) and of group (stutterers and nonstutterers) in the analysis of variance as well as the mean duration of the intervals for both groups.

Intervals	Initial sound F (df 3,102)	group F (df 1,34)	mean interval in msec	
			NST	ST
Speech reaction time	7.61^{xxx}	18.04^{xxx}	563	748
Latency time	4.38^{xx}	17.79^{xxx}	353	496
Int_{r-l}	3.54^{x}	5.06^{x}	332	406
Int_{l-t}	0.82	7.12^{x}	26	96
Initiation time	7.52^{xxx}	2.53	210	252
Int_{t-g}	1.31	0.05	67	71
Int_{g-t}	6.23^{x}	3.03	136	171

x $p < .05$; xx $p < 0.1$; xxx $p < .001$

As shown in Figure 4, the highly significant differences among sounds in speech RT mainly result from a longer speech RT for utterances with initial /s/. In the first part of the speech reaction time (latency time) there was only a small sound effect although it is significant. This effect was mainly caused by a slightly longer latency time of 22 msec) in /p/-utterances. Also the lip RT differed slightly and significantly, because of the shorter lip RT's in /s/ utterances compared to /o/ and /p/ (360 msec vs 379 and 380 msec). The initiation time showed a small but highly significant difference for initial sound, caused mainly by a much longer interval for /s/-utterances (38 msec), which may possibly be a result of slower signal detection for the high frequency of /s/. Within the initiation time there were no differences between /a/ and /o/ for Int_{t-g}, but the last interval (Int_{g-s}) is significantly shorter for /o/. It must be noted that the effects of initial speech sound on the various intervals are the same for stutterers and nonstutterers. For each of these intervals the group x sound interaction was far from significant.

Group effect. The differences between stutterers and nonstutterers in the analyses of variance as well as the group means are presented in Table 2. In this table the interval data are averaged over initial sounds (and, as before, over utterance lengths, task and reaction time condition). As stated before, RT-lip was not averaged over the four initial sounds but only over /o/, /p/ and /s/; the two intervals in the initiation time (Int_{t-g} and Int_{g-s}) are averaged over /a/ and /o/ only.

In speech reaction time stutterers were much slower than nonstutterers; the difference was highly significant (p .001). This difference (185 msec) consisted for the most part of a difference in latency time (latency time differed 143 msec and initiation time differed 42 msec).

Considering the two intervals within the latency time, it can be seen that the total between-group difference of 143 msec was about equally divided between Int_{r-l} (74 msec) and Int_{l-t} (70 msec). Both intervals were significantly longer in stutterers than in nonstutterers. The nonsignificant difference in the initiation time (42 msec) was mainly attributable to the last interval, i.e. Int_{g-s} (35 msec), but of course this difference was not significant either ($p = .09$).

Effect of utterance length and task preparation.

The main hypothesis of this study concerns possible differences between stutterers and nonstutterers in the effect of utterance length and task preparation on the latency and initiation times.

The main effects of utterance length (one syllable versus polysyllabic words versus sentences) and of task preparation (immediate versus delayed reading) were very strong on speech RT and on the various intervals. In Figure 5 the data for one syllable words, polysyllabic words and sentences are presented for both groups separately in both the delayed and the immediate reading task. In this figure, the reaction times of the four recorded signals not the duration of the various intervals, are displayed separately. It should be noted that in Figure 5 the dimension

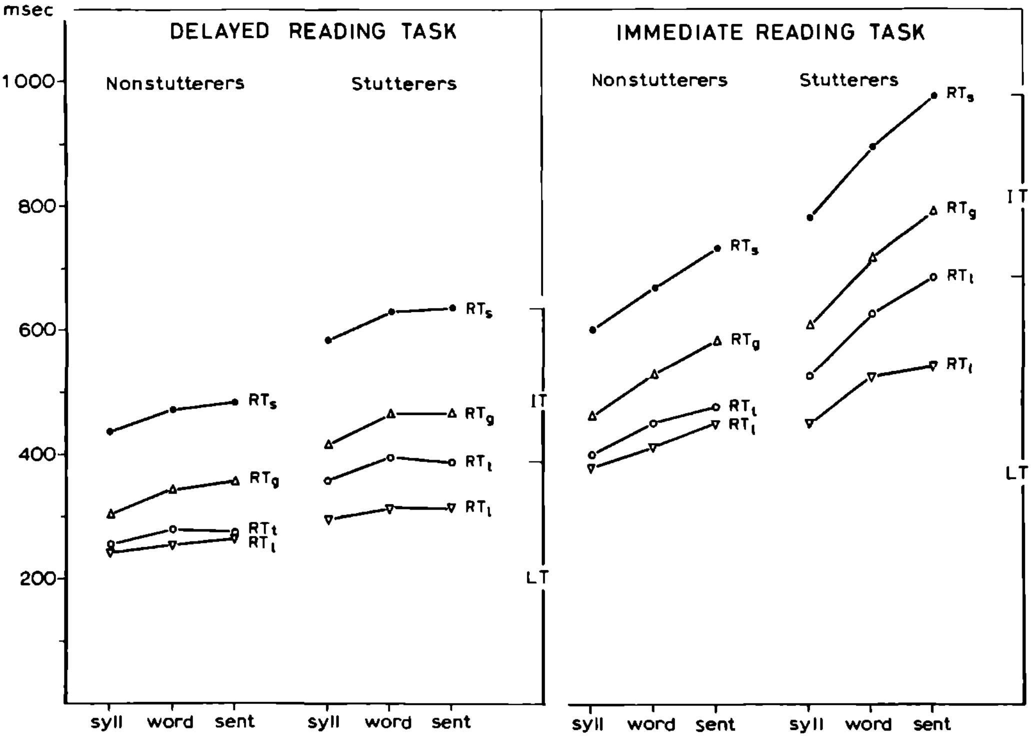

Figure 5: Mean reaction time scores in the delayed and immediate reading task for EMG activity (RT_l), throat EMG activity (RT_t), initial glottal closure (RT_g) and the onset of speech RT_s) in one-syllable words (syll), polysyllabic words (word) and sentences (sent). The reaction time data are lined up from the response signal (= 0 msec). RT_s and RT_t are averaged over /a/, /o/, /p/ and /s/, RT_l is averaged over /o/, /p/ and /s/ and RT_g is averaged over /a/ and /o/ only.

of time is represented on the vertical axis, unlike Figure 4.

Table 3 gives the most important values of the analyses of variance for each of the 7 dependent variables, i.e. the F-values of the main effects of utterance length and task preparation as well as their interaction. The hypothesis predicts a larger length and task effect for stutterers, therefore the interactions of both length and tasks with groups are also given in Table 3.

Effect of utterance length. As might be expected in utterances of increasing length the reading of the utterance, the motor planning and possibly the initiation of speech consume significantly more time. As shown in Figure 5 the difference between one-syllable words and polysyllabic words was much larger than that between polysyllabic words and

Table 3: Summary of the main effects of utterance length (one-syllable words, polysyllabic words and sentences), task (delayed and immediate reading task) and speed (normal RT condition and time stress RT condition) as well as the length x task, length x group (stutterers and nonstutterers), task x group and speed x group interaction for each of the intervals between the response signal and the onset of speech.

Interval	length F(df 2,68)	task F(df 1,34)	speed F(df 1,34)	length x task F(df 2,68)	group x length F(df 2,68)	group x task F(df 1,34)	group x speed F(df 1,34)
Speech reaction time	74.96xxx	85.07xxx	106.59xxx	31.15xxx	2.16	1.54	6.28x
Latency time	60.52xxx	260.17xxx	72.48xxx	19.42xxx	5.66xx	5.38x	5.64x
Int_{r-l}	25.05xxx	169.65xxx	85.99xxx	13.74xxx	1.18	1.81	4.66x
Int_{l-t}	2.83	3.84	4.78x	2.93	4.60xx	1.84	1.12
Initiation time	9.77xxx	2.35	58.09xxx	2.06	0.24	0.01	1.98
Int_{t-g}	8.44xxx	6.18x	13.74xxx	1.55	0.12	0.11	0.01
Int_{g-s}	0.23	0.32	48.84xxx	1.42	0.02	0.01	1.35

x $p < .05$; xx $p < .01$; xxx $p < .001$

sentences. This was true for practically all relevant intervals in both tasks. This change in the direction (the angle) in Figure 5 may result from a different strategy used by some of the subjects in producing the sentences. Some subjects, in an effort to respond as quickly as possible, concentrated on the first word of the sentence, saying it quickly and than said the rest of the sentence more slowly. Others said the whole sentence quickly. It is interesting that the effect of length is not the same for all intervals. In both groups the intervals in the period between the response signal and the initial closure of the vocal folds (RT_g in Figure 5 and latency time, Int_{r-l} and Int_{t-g} in Table 3) are strongly influenced by utterance length. Within these periods greater utterance lengths result in larger intervals, producing a sort of spreading effect. The effect of utterance length is stronger for the latency times (LT in Figure 5) than for initiation time (IT in Figure 5) although for the latter the effect of utterance length is also significant. The significant effect of length on initiation time is attributable to the first portion (Int_{t-g} in Table 3), which is significantly influenced by length. There is no significant effect of length on the second portion (Int_{g-s}) of the initiation time. This can also be seen in Figure 5, where the curves of RT_g and RT_s are parallel.

One of the main questions of this study was whether stutterers show a larger effect of utterance length than nonstutterers. Close inspection of

Figure 5 reveals that this is true for RT_s in both tasks. Averaged over tasks (the higher order interaction between task length and groups was not significant for any of the intervals) the difference between words and syllables was 79 msec in stutterers and only 52 msec in nonstutterers. This difference contributes to the group x length interaction, which was notsignificant ($p = .12$). It is remarkable that some intervals, i.e. latency time and Int_{l-t} do show a significant group x length interaction (see Table 3) although their length effects are smaller than for RT_s. For example, the difference between words and syllables in latency (70 msec in stutterers and 41 msec in control subjects) contributes most of the difference in RT_s, but, probably because this group difference in LT is more pronounced, the interaction in LT reaches significance.

Task effect. As shown in Figure 5 speech reaction time is much longer in the immediate reading task than in the delayed reading task and these differences were much larger in longer utterances. This is easy to understand because the subject has to read the utterance after the response signal in immediate reading, which takes more time in longer utterances. The task effect was much stronger in the latency time (for delayed reading 319 msec versus 515 msec for immediate reading) than in the initiation time (212 msec for delayed reading versus 244 msec for immediate reading). Although the task effect for the entire initiation time was not significant ($F = 2.35$) the first portion of the initiation time (Int t-g) differed significantly ($F = 6.18$) between tasks. As in the length effect, the last interval before the onset of speech (Int_{g-s}) was not influenced by the task differences.

The second hypothesis that was tested in this study was whether stutterers show a greater difference between delayed and immediate reading tasks than nonstutterers. Averaged over utterance length, the difference between both tasks in RT_s amounted to 262 msec in stutterers and 200 msec in nonstutterers. However, the difference between these values, i.e. the group x task interaction, was not significant ($p = .22$). Although smaller, the difference in latency time between both tasks (228 msec in stutterers and 171 msec in nonstutterers) produced a significant group x task interaction (see Table 3). It is remarkable that the group x task interactions give the same pattern of slightly inconsistent results as the group x length interactions.

Effect of speed

The instruction to respond faster was assumed to result in an increase in the percentage of dysfluencies and probably in greater differences between stutterers and nonstutterers in the timing of the fluent utterances. Contrary to this expectation the frequency of stuttering did not increase in the time-stress condition, but instead showed a tendency to decrease (see Figure 3). From observations during the experiment it became quite clear that speech quality clearly differed between both speed conditions, which was confirmed in the perceptual judgment experiment is described below. When urged to respond as quickly as possible, both stutterers and nonstutterers adopted another strategy of speech behavior. Specifically, they produced utterances with less pitch variations and less clear articulation. Consequently, it was not possible to answer the question regarding the influence of speed on timing, since an unusual manner of speaking was used in which the speaking task may have been motorically simplified. This interpretation may be confirmed by the fact that the frequency of stuttering was also reduced in the time-stress condition, perhaps because of the motorically simpler manner of responding.

The durations of the various intervals in both speed conditions are given in Figure 6, for both groups averaged over all other relevant variables.

As can be seen in that figure the speed condition has a strong

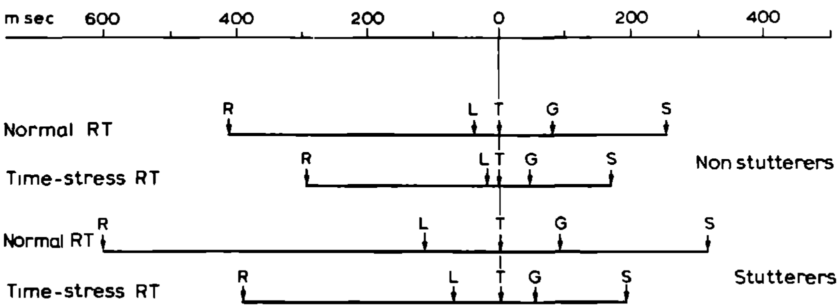

Figure 6: Timing of laryngeal and articulatory movements between the response signal (R) and the onset of speech (S) for nonstutterers (NST) and stutterers (ST) in the normal reaction time condition (normal RT) and time stress reaction time condition (time stress RT).

influence on the duration of the various intervals. As in Figure 4 the data are aligned in this figure from the start of throat muscle activity (T) which shows that the speed effect influences latency as well as initiation time. It is quite clear that in a RT-condition in which fast responding was additionally stressed the interval times are much smaller. All the intervals show the same speed effect to the same extent and these effects are highly significant (Table 3). It is interesting to note that the reduction of the intervals with speed was more or less proportional to the overall reduction in RT_s. For the nonstutterers the RT_s in the speed condition reduced to 70% of the normal RT_s; this reduction was divided about equally over the four successive intervals; RT_1 73%, Int_{l-t} 50%, Int_{t-g} 55% and Int_{g-s} 73%. The reduction for stutterers was much higher in absolute terms (the group x speed interactions were significant for all intervals), but also slightly higher when expressed in percentages. This reduction was even more consistent for the intervals: 64% for RT_s, 66% for RT_l, 62% for Int_{l-t}, 57% for Int_{t-g} and 70% for Int_{g-s}.

Speech quality. As mentioned before, the frequency of stuttering was slightly but significantly lower in the time-stress RT condition than in the normal RT condition. To measure possible changes in speech quality under time stress, a judgment experiment was carried out on speech samples from both RT conditions. In Table 4 the mean scale values for the ratingscales in both RT conditions as well as the F-values and p-values from the analysis of variance for each scale value are presented. From these results speech production in the time stress condition can be described as faster, much less clearly articulated, produced with less pitch variation and more unnatural (see Table 4). This was true for stutterers and control subjects alike, with the exception of the slow-fast rating scale. In the normal RT condition the stutterers are relatively slower than nonstutterers compared with the time stress RT condition which difference can be seen also in Figure 6. In general, both groups probably attempted to reduce the motoric complexity of the response.

Effect of stuttering severity

The classification of stutterers into very mild, moderate and severe stutterers was based on mean scale values of clinical judgements made from conversational speech and reading. The mean score of these classifi-

Tabel 4: Mean scale values for rating scales in the normal RT condition and the timestress RT condition for stutterers and nonstutterers as well as the condition effect and the group x condition interaction in the analysis of variance. The scale values ranged from 1 to 7 while the second one of each pair has the higher value.

	Mean Scale Value					
	Normal RT		Time Stress RT		Condition	Group x condition
Rating scale	NST	ST	NST	ST	(F(1,9)	F(1,9)
Slow-fast	4.48	3.43	5.67	5.19	177.45xxx	6.50x
Unnatural-natural	4.01	3.44	3.15	2.98	12.00xx	1.13
Monotonous-with inflection	3.53	3.15	3.22	2.73	6.75x	0.18
Quiet-loud	4.07	4.04	4.05	4.02	0.01	0.00
Unclear-clear articulation	4.07	4.26	3.00	2.67	81.25xxx	0.19
Toneless-clear voice	3.87	3.65	3.91	3.30	0.83	1.28

x $p < .05$; xx $p < .01$; xxx $p < .001$

cations did not correlate very highly with the fluency percentage of speech during the experiment, the latter being averaged over all four experimental variables (Pearson r = .503). This is easy to understand because the experiment exposed the subject to a very specific situation with respect to speech, which was strongly structured. The clinical judgment included more aspects of normal speech and offers, therefore, a better representation of stuttering severity. To include all stuttering subjects the data analysis was carried out only on one-syllable utterances, since for this length only at least one or more fluent utterances were available for each stimulus category in all stuttering subjects. Figure 7 shows the various interval times between the response signal and speech onset lined up from the start of throat EMG activity.

All three subgroups present about the same picture. There were no

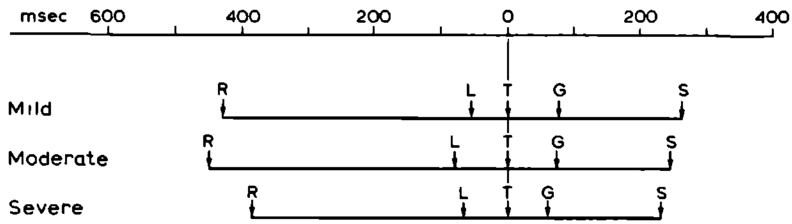

Figure 7: Timing of laryngeal and articulatory movements between the response signal (R) and the onset of speech (S) in one-syllable utterances for mild stutterers (n=5), moderate stutterers (n=9) and severe stutterers (n=6).

differences between the mild and moderate stutterers. Contrary to expectations the severe stutterers (6 subjects) tended to be a little faster in nearly all intervals than the mild (5 subjects) and moderate stutterers (9 subjects), but none of these differences is significant at all (F values for all intervals <1).

Analyzing only the one-syllable utterances eliminates the effect of utterance length. This effect was tested however by only using the data from mild and moderate stutterers. Utterance length turned out to have an equal effect for both groups. The same analysis was tested for a task effect. Interestingly, the difference in RT_S between both tasks was not the same for mild and severe stutterers, but higher for the group that stuttered less ($F(1,12) = 5.40$, $p < .05$).

8.4 DISCUSSION AND CONCLUSIONS

The purpose of this study was to compare two explanations for the longer reaction times that stutterers usually demonstrate: programming and initiation. It was hypothesized that the inability of stutterers to start seaking rapidly is caused by either a deficit in the programming of the motor commands necessary for the initiation of an utterance or by more peripheral disturbances in the initation of one or more of the physiological components required for fluent speech. This problem was approached in two ways. The first approach was to manipulate experimentally two variables that are assumed to influence the degree of programming taken place, i.e. utterance-length and type of task. The second approach was to divide the total speech reaction time into a number of intervals, and to investigate whether the group differences would be greater in the earlier intervals or towards the end of the reaction-time. In the discussion below each of these approaches will be discussed in more detail. First, however, the effect of the experimental variables on the number of disfluent utterances will be summarized.

The disfluency percentages found in the present study replicate the results of earlier studies, reviewed by Tornick and Bloodstein (1975) and Van Riper (1982). Most of the disfluencies occurred at (or close to) the beginning of an utterance. The percentage of disfluencies within words or sentences was much lower. The initial sound (/a/, /o/, /p/, and /s/) did not influence the percentage of stuttering. This was true only when averaged over subjects, since some of the stutterers had more trouble with /p/, while a few others had more trouble with either the voiced or the voiceless sounds.

One of the clearest findings in the present experiment was the greater percentage of initial disfluencies in longer utterances. Polysyllabic words elicited more than twice as much stuttering as monosyllabic words, and at the beginning of sentences the effect of length was even more pronounced. The difference between the two tasks in initial disfluencies was much slighter than the length effect, although still significant. It is interesting that the difference between words and sentences in the percentage of stuttering was greater in the immediate reading task than in the delayed reading task. In the delayed reading task, the subject was asked to read the text at least once in advance. Moreover, under these conditions the subject was given the opportunity to prepare the motor sequence, and to adopt an appropriate posture for the articulators and muscles involved in the intended utterance. The latter aspect - prepos-turing - was probably the same for short and long utterances, since the initial sounds were identical for the three utterance lengths. Therefore, explanations for this task effect should be sought in other processes. Two candidates easily suggest themselves: the more elaborate linguistic processing and the more extensive motor programming required for longer utterances. These possibilities will be discussed at greater length below.

In the delayed reading task, the percentage of stuttering was found to be slightly lower than in the immediate reading task. This finding can be used as an argument against theories that try to explain stuttering as behavior evoked by increased anxiety resulting from negative anticipation processes. Bloodstein's (1974) "anticipatory struggle hypothesis" and Brutten and Shoemaker's (1967) "negative anticipation theory" both predict increased stuttering in the delayed reading task.

The fluent utterances of stutterers were found to have a much longer speech RT than the utterances of nonstutterers (averaged over all experi-mental variables the RT of stutterers was 748 msec vs. 563 msec for the controls). This is not a new finding, however, and earlier studies demon-strating this difference in RT were discussed in the introduction. In this study, the first approach to explaining this RT difference was to assess the effects on the subjects' reaction time of the experimental variables, which were supposed to influence the programming of speech. These effects were quite subsantial. Longer utterances were preceded by a much longer reaction time, and the speech RT in the immediate reading task was considerably greater than in the delayed reading task, the latter effect being stronger for longer utterances. Most of these effects have nothing to do with motor programming, however, since the information processing necessary for word recognition and meaning analysis in reading will obviously take more time if the reading material is longer. Also, these cognitive activities will take more time in an immediate reading task in which the words can not be read before the response signal. However, it was decided to manipulate these variables anyway, because, in addition to the input processing activities just mentioned, the motor output should at least partly be prepared or programmed before the start of the acoustic output. Such programming is assumed to take time. If stutterers need the same amount of time for input processing as nonstutterers, but have greater difficulties in output programming, then this should show up in longer reaction times, particularly for longer utterances and in the immediate reading task in which the output could not be programmed before the response signal.

The results of this study were not completely in agreement with these predictions. The differences in speech reaction time caused by utterance length and by type of task were slightly greater for stutterers than for control subjects, but the results were not significant. However, the length and task effects on throat-EMG reaction time (RTt, designated as latency time in the foregoing section) produced statistically significant interactions. This is remarkable since RTt showed the same pattern of results as speech RT, and produced most of the speech RT differences. Probably, this difference in statistical significance between speech RT and RTt resulted from a slightly lower error variance and a slightly more pronounced interaction.

A major purpose of the investigation was to identify in which of the four successive RT intervals the main effects of length and task were most clearly observed, not taking into account the group differences. Since programming is supposed to occur, at least in part, before the first motor command is executed, it should be possible to trace the effects of programmingvariables in the first interval, i.e. lip RT. The results confirm this prediction. Lip RT showed the greatest effects of length and task. In the second interval (Int l-t), the effects showed the expected trend, but were not significant. The third interval, i.e. between laryngeal EMG onset and glottal closure (Int t-g), did show clear and significant effects. Only the interval closest to speech onset (Int g-s) remained completely unaffected. This fact argues against an alternative interpretation of the length and task effects: a gradual slowing down under the more difficult conditions of all the processes preceding speech onset. It is interesting that a general speeding up of all intervals was observed under the time-stress condition compared to a normal reaction condition, each interval decreasing in proportion to the total decrease. However, the effects of length and task were different, since the final interval remained uninfluenced by these variables. This could mean that the additional cognitive processing and programming required for longer utterances and for the immediate task is completed before initial glottal closure. Alternatively, one might suppose that the programming processes continue, but that the final interval reflects a more passive process, dictated primarily by the speed with which subglottal air pressure reaches the level required for phonation, and resulting in less variability in duration.

The second approach to the question mentioned above was to split up the total speech reaction time into segments or intervals in order to test whether for stutterers latency or initiation intervals are prolonged most. The dichotomy between latency and initiation may be somewhat confusing. Theoretically, the very first manifestation of physiological activity should be used as the dividing line. For utterances starting with /o/, /p/, and /s/, the first activity turned out to be lip EMG. Utterances starting with /a/ had throat EMG as the first physiological manifestation. In order to combine the data from each of the four initial sounds as much as possible and to avoid unreadable abbreviations, the interval between the response signal and throat EMG was treated as latency in the foregoing section. This was justified, since the throat EMG reaction time was more or less equal for the four initial sounds. However, in the discussion below this use of the term will be avoided, and "latency" will designate the silent period between the response signal and the first physiological activity regardless of its location.

The answer to the question whether latency or initiation is involved most in stutterers' longer speech RTs is ambiguous for another reason: it seems that both periods are involved. The first interval (lip RT) was longer for the stutterers by 74 msec. The next interval (Int l-t) was longer by about the same amount of time (70 msec), while the third interval (Int g-s) was longer for stutterers by a statistically nonsignificant 42 msec. The most striking aspect of Figures 4 and 6 is that for nonstutterers the lip and throat EMG activities occurred almost at the same moment, while for stutterers there was a substantial delay between lip and throat EMG.

Stuttering has frequently been ascribed to problems during the onset of phonation (Freeman & Ushijima, 1977; Conture, McCall & Brewer, 1977) or to the coordination of respiration and phonation (Watson and Alphonso, in press; Peters & Boves, 1986, in press) or to the coordination of phonation and supraglottal articulation (Ford & Luper, 1975; Yoshioka & Löfquist, 1981). In none of these studies the reaction period is split up into intervals. Therefore, these studies cannot be used to make very precise predictions with regard to which of the four intervals will be prolonged for stutterers. However, if phonation is the main problem, this implies that the longer reaction times of stutterers are caused mainly by a lengthening of the periods just before or just after the start of laryngeal activity. It is interesting that in this study only the period before throat EMG was longer.

In Peters and Boves' study (1986, in press) it was found that stutterers showed a higher percentage of deviant patterns of subglottal pressure build-up than nonstutterers - a difference of between 14 and 32 per cent depending on the initial sound. In most of these deviant patterns, it took longer for the pressure to reach the appropriate level than in nondeviant patterns. Consequently, one would expect the time between glottal closure and speech onset to be longer for stutterers in the present study. The difference of 42 msec that was found did not reach statistical significance, possibly because the percentage of trials with delayed pressure build-up was too low.

The approach of subdividing the total reaction time seems to be quite obvious one, yet it has not often been used. There are two exceptions: a study by Shipp, Izdebsky and Morrissey in 1984, which reports data pertaining to normal subjects only, and a study by Bakker and Brutten (in press). In the latter study the lip RT in saying /pa/ did not differ between stutterers and controls, but voice initiation, the time between the onset of lip EMG activity and the first electroglottographic sign of vocal cord vibration, was considerably longer for stutterers. Lip RT differed in the present study, probably because the utterances were more speech-like and varied much more than in the Bakker and Brutten study. The second part of their results was replicated here.

The third variable that was experimentally manipulated was time stress. Under the normal reaction time conditions, all intervals were considerably longer than under the condition in which very fast responding was stressed by giving feedback about reaction times. Unfortunately, the quality of the speech was much lower under the time-stress condition. The results of an additional perceptual judgement procedure performed on a number of utterances taken from the normal and the time-stress conditions made this very clear. A lower degree of articulatory accuracy under the fast response condition may also be responsible for the unexpectedly lower disfluency under the time-stress condition. These findings raise a methodological point concerning the speed-accuracy trade-off, which is seldom recognized and never measured in speech RT studies.

The lowered speech accuracy found under the time-stress condition makes the investigation of any supposed disorganization of physiological processes under time stress less meaningful. Still, it is interesting that stutterers, after speeding up the onset of speech even more than the normal controls, were able to reduce their stuttering by making their articulation less clear. This finding argues against a simple timing hypothesis which explains stuttering entirely by the inability to initiate all simultaneous speech activities at the right time.

The classification of stutterers into three subgroups, on the basis of the severity of stuttering as assessed in a prior clinical procedure, resulted in a number of nonsignificant but interesting results. Borden (1983) and Watson and Alphonso (in press) found differences between severe and moderate stutterers. Severe stutterers tended to have longer RTs while moderate stutterers behaved almost normally under some conditions. The reaction time and interval results of the present study do not replicate these findings. A significant group effect was found in none of the analyzed intervals. If anything, severe stutterers showed even shorter interval durations than the other groups. It is possible that these severe stutterers were less inclined or able to use a strategy to slow down the speech onset or to increase fluency.

Summarizing the disfluency and RT results, it can be concluded that stutterers encounter most difficulties at the beginning of utterances, particularly when these utterances are longer. The programming hypothesis was supported by the data, since the stutterers' RT was considerably lengthened in the initial interval, i.e. the interval before the first sign of (lip) EMG. Moreover, the effects of utterance length and type of task were greater for stutterers, at least if they were measured during the first two intervals, i.e. in the throat EMG RT. However, the alternative explanation, namely that the main difficulty is the initiation of an utterance, was also supported by the data. This was most clearly shown by the longer lapse of time between the onset of lip EMG and the onset of throat EMG for stutterers. However, the absence of large group differences in the final two intervals does not support the initiation explanation.

The dichotomy into motor programming and initiation is much too simple, however, and a few alternatives will now be discussed. One the the main problems in RT research is that a longer RT may be explained in two different ways. It may signal an underlying inability in starting the movement or it may be the result of a strategy that the subject has learned to overcome this (or another) inability. The strategy of slowing down the response is often very effective in producing fluent speech and is often used in fluency shaping therapies (Ryan, 1974; Webster, 1975). The finding that the severe stutterers seemed to have the shortest RT suggests that they may have used such a strategy. On the other hand, the fact that the Int g-s was not longer for the longer utterances complicates this interpretation somewhat, but cannot be used as conclusive evidence against it.

In both of the above interpretations the longer RT signals an underlying problem. In most of the preceding text it has been assumed that this problem is basically motoric. But the data of the present experiment are insufficient to determine the precise nature of this motoric problem. For example, the effect of utterance length on stuttering and reaction time may be explained by the need for more extensive motor programming for longer utterances. However, the effect of linguistic factors cannot be excluded. According to an effort or attention hypothesis, stuttering may be aggravated because of the necessity of combining linguistic processes with motoric processes. If it is assumed that the problems stutterers have in their speech motor output can usually be surmounted by making more of an effort, or by giving the process more attention, then necessarily their motor output deteriorates when they have to divide their attention. Reading long words or sentences, particularly under unprepared conditions (i.e. not having seen the test beforehand), may require more attention for the cognitive process involved in reading, thereby interfering with motor preparation. This linguistic interference interpretation may be tested against a motor programming hypothesis by manipulating the reading material along linguistic dimensions, such as word frequency, and independently along motoric dimensions, such as the length of the consonant clusters or the number of lip movements that have to be made for the utterance.

The great effect of utterance length may be explained alternatively by a deficiency in programming. According to a programming view (see Gracco, in press; Hulstijn, in press), utterance length affects the number of muscle commands that have to be encoded or that have to be retrieved from a motor store. In the delayed reading task, this motor programming can be executed before the response signal, at least according to some authors (Klapp, 1976; Schmidt, 1982). The finding that stuttering was reduced in this delayed reading task is in agreement with the programming hypothesis, but the fact that this effect was very small, and that it was found only for sentences, notably only under the time-stress condition, argues against such a programming view. Only if Sternberg's view of the programming hypothesis (see Sternberg, 1978) is adopted, which denies the usefulness of advance programming in tasks such as the delayed reading task, can the motor programming hypothesis be upheld.

In future research, the motor programming hypothesis should be contrasted with views that explain stuttering as a defect in the coordination or timing of the many simultaneous activities that are required for fluent speech (see Harris, in press; Watson and Alphonso, 1983). The most important experimental variable in testing the programming hypothesis should be the number of motor units (syllables or phonemes) in the utterance. Coordination can be made more difficult by trying to vary the number of subsystems. However, theoretically, coordination is mostly restricted to activities that take place in a much shorter time period, say a few hundreds of milliseconds, compared to the time span over which the programming of a three syllable word is extended. Timing demands should be manipulated by varying the speed of speech independently from the duration of the utterance and by asking testees to stress different syllables in turn (Tuller, Kelso and Harris, 1982; Harris, in press).

In our view, simply comparing stutterers with control subjects with respect to the duration of the various intervals, or with respect to reaction times, is not enough to further insight into the nature of stuttering. Instead, the effect of experimental variables on the differences in timing patterns between stutterers and controls should be investigated. All this requires an extended program of research. A program on which we have already embarked.

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In the past stuttering has often been approached as an exclusively or primarily emotional problem. While initially the basic assumption was that stuttering should be looked upon as a neurosis, later, under the influence of psychological theories of learning, there was more emphasis on tensions or emotions directly related to speaking, which could elicit or cause disturbances in fluency. In recent years in the approach to the problem of stuttering there has been a gradual shift in attention towards the speech motor aspects of the disturbance. This thesis is a collection of experimental studies in which this shift in attention regarding the approach to the problem of stuttering is reflected.

In the first part of this thesis (part A) the relationship between stuttering and anxiety is studied more closely. The experimental research into this matter is introduced in the **first chapter** in which the most influential approaches to stuttering in past decennia are ordered on the basis of the place and function of anxiety or tension in speaking in each of these approaches. A subdivision is made into (1) approaches in which anxiety is thought to precede stuttering, and tence to elicit it, (2) the multi-factored views in which anxiety is considered a relevant, but not a causal factor, and (3) the views in which anxiety in speech situations is thought to be a direct consequence of stuttering. Next, the experimental research into the various aspects of the relationship between stuttering and anxiety are discussed. This investigation yields little evidence for a direct aetiological relationship between stuttering and anxiety. However, the investigation in question has many limitations and, as a result, does not allow far-reaching conclusions. Especially in a clinical framework a multi-factored approach to the problem of stuttering seems an attractive point of view. As yet, clinically such an approach yields the most possibilities of paying attention to a great many specifically individual aspects of the problem of stuttering.

In the **second chapter** an experiment is described in which aims to investigate to what extent the anticipation of speech situations involves an increase in the level of tension, as a result of which speech motor disturbances could be elicited. To this end differences in subjectively experienced tension and physiological activity (electrodermal activity, vasomotor responses and heart rate) were examined for 24 stutterers and

24 nonstutterers shortly before and during the performance of speech tasks (reading and spontaneous speech) and non-speech tasks (the motor and intelligence tasks). Differences between stutterers and nonstutterers principally emerged in the anxiety ratings after the performance of a task. The greatest differences occurred after the performance of the speech tasks, and hardly after performance of the other tasks. In the measured values of the physiological activity before and during the performance of speech tasks these emerged no differences between stutterers and nonstutterers. However, the measured values in speech situations did turn out to be higher than in non-speech situations, but this was the case for both groups. This points to the presence of a somewhat more general communicative stress factor in speech situations for both groups. Further analysis of the development of the arousal level during the tasks showed that for nonstutterers there was a faster decrease during performance of the tasks. On the basis of the results of this experiment it can be concluded that the differences between stutterers and nonstutterers (as a group) with respect to anxiety are less great in speech situations than is often thought. If there are differences, they manifest themselves in the speech situation itself, not during the anticipation period preceding the speech task. This indicates that tension or anxiety in speech situations should be regarded as a consequence of the stuttering rather than as an antecedent condition.

The lack of significant differences between the groups in physiological activity (arousal level) may have been caused by greater individual differences within the group of stuttering testees. If the problem of stuttering is approached from an anxiety-theoretical point of view, it is to be expected that for seriously affected stutterers a higher level of anxiety will be displayed dominantly. In order to investigate the influence of the seriousness of stuttering, the data of the experiment described in chapter two are further analysed in **Chapter three** for different levels of seriousness in stuttering. To this end the group of stutterers was divided into three subgroups on the basis of the frequency of stuttering during the speech tasks: low, moderate and high frequency stutterers. The average levels of measurement for the spontaneous fluctuations in the electrodermal activity, the vasomotor reactions and the heart rate, differed neither in the anticipation period, nor in the performance of the tasks for the three subgroups. However, with respect to electrodermal activity, there was a difference in skin conductance level in that the group of high frequency stutterers showed a higher skin conductance level than the groups of moderate and low frequency stutterers, who in turn did not differ from the nonstutterers. This tendency also showed up for the non-speech tasks. As for the development of the arousal level, it turned out that in repeating the same task the subgroup of high frequency stutterers adapted more quickly than both the other subgroups of stutterers for whom the decrease of the arousal level develops in the same way as for nonstutterers. However, within the same task it turned out that the adaptation process for each of the three subgroups of stutterers developed in the same way.

Despite the fact that the differences in the measured values of arousal between the three subgroups only occur in the skin conductance values, and although these differences are slight and only marginally significant, the analyses of chapter three refine the general conclusions of chapter two. These conclusions seem to be valid for low and moderate frequency stutterers, but possibly they are valid to a lesser extent for the high frequency stutterers, who show a tendency for a higher arousal level, both in anticipating a task and during its performance. A number of explanations for this is adduced at the end of chapter three. Chapter three ends with a consideration of both the limitations of the research described and the problems in interpreting the measurements of arousal, as a result of which the research data do not allow generalisations. On the one hand, the interpretation of physiological measures of anxiety is extraordinarily difficult; on the other hand, with these only physiological component of the response complex "anxiety" is measured. Furthermore, in this investigation the subjective experience of anxiety is measured afterwards by means of a scale method the reliability and validity of which is disputable; also, no changes in behavior related to anxiety or tension were measured. The real relationship between stuttering and anxiety is far from clear. In the investigation described there is no evidence for the approach to the problem of stuttering which views it as being caused by a general factor of anxiety. Further research into the relation between stuttering and anxiety is desirable, but will be very complex. Chapter three ends with a discussion of the experimental-methodological problems that occur in investigating the effect of tension or anxiety on speech behavior.

The second part of this thesis (part B) is concerned with the various aspects of the speech motor system of stutterers. **Chapter four** introduces the experimental investigations which are described in chapters five to eight. This chapter starts with a description of the motor and physiological processes during speech, as well as the levels at which these can be measured. This is followed by a survey of recent research in the speech physiology of stutterers and a description of the main views in which stuttering is primarily conceived as a disturbance of the speech motor system. Previous research in speech physiology has shown that in the fluent and non-fluent utterances of stutterers a number of irregularities occur, not observed with nonstutterers, both within the individual motor subsystems involved in speech - respiration, phonation, and articulation - as well as in the coordination between these subsystems. Especially during the onset of speech movements various abnormalities are viable to occur, such as an increased laryngeal muscle activity, an inadequate coordination of the intrinsic laryngeal muscles, inadequate timing of lip, jaw and tongue movements and a deficient coordination of respiratory, phonatory and articulatory movements. Furthermore, the onset of the speech movements appears to take place at a slower rate for stutterers.

In chapters five to eight a number of personally conducted studies are described in which various aspects of the onset of speech movements is investigated more closely.

In **chapter five** an investigation is discussed in which the realisation of the voice onset is examined at the perceptual and acoustic levels. The even and gradual initiation of the voice onset is an important part of the therapy in many treatments of stuttering. The evaluation of the voice onset in clinical practice takes place on the basis of auditory judgement. Little is known about the reliability and validity of such judgements. In the research described in chapter five the reliability of the auditory judgements by trained assessors (speech therapists) of the abruptness or gradualness of the voice onset was determined. It turned out to be reasonable, but not especially high (intra-class correlation = .74, the stimulus range being very wide). Next, six acoustic measures were developed to describe the amplitude envelope of vocal-consonant utterances. Subsequently, the usefullness of these measures as predictor of the observed voice onset was investigated, making use of correlation and multiple regression analyses. It turns out that the logarithm of the time the amplitude needs to increase from 10% to 90% of its maximum level is the most powerful predictor of the observed abruptness of the voice onset. Provided that the measure is scaled correctly, it turns out to be comparable to a "typical" assessor. The other measures, which were deduced from an approximation of the envelope by a sequence of line segments and the maximum amplitude achieved in the stimulus, appear to contain essentially the same information as the rise time measure. The investigation shows that the log-rise time was a useful predictor of the observed abruptness of the voice onset, and because of that offers promising possibilities for the construction of a simple device to assist the voice and speech therapist in determining the abruptness of the voice onset. Chapter five ends with a description of a blueprint for the design of such an instrument.

The research described in **chapter six** is concerned with the aerodynamic processes which are operative during the onset of phonation. It was investigated how the subglottal pressure level, necessary for the onset of phonation, is built up in the fluent speech utterances of stutterers and nonstutterers under different conditions. According to a number of researchers, the incapacity to coordinate the respiratory movements in the correct way, the larynx being globally set in preparation of phonation, is a major cause of disturbances in the gradual onset of phonation. Systematic research into the coordination of expiration and the adjustment of the larynx is not available as yet. In this investigation five different types of subglottal pressure build up could be detected, with a high degree of reliability. These types could be given a clear and insightful physiological explanation. In normal speech it turned out that stutterers used unusual patterns of subglottal pressure build up significantly more often in fluent speech utterances than nonstutterers (26.6% vs 3.1%). The occurrence of deviant types of pressure build up was not related to the degree of stuttering.

In the investigation the effect of different modes of speaking was also investigated. Prior to the investigation the testees were trained in two speech strategies which are often used in stutter therapies, i.e. speaking with a very gradual voice onset and speaking with reduced articulatory effort. The effect of these experimental speech conditions turned out to be very different: while speaking with a gradual voice onset affects the subglottal pressure build-up directly, speaking with reduced articulatory effort had no effect on it. The effect of the frequency of occurrence of the various types of subglottal pressure build-up was the same for both groups. Because the training time necessary for both groups was the same it can be concluded that it is not more difficult for stutterers than for nonstutterers to perform specific phonatory or articulatory manoeuvres.

In **chapter seven** the interactions between respiration, phonation and articulation are studied more closely. The frequency of the various types of subglottal pressure build-up (Psg) described in chapter six was related to characteristics of phonation and articulation. To this end both the vocal cord activity, as reflected in electroglottographical registrations (EGG), and the audio signal were registered together with the subglottal pressure. A qualification system was developed for the signal analysis of the EGG, which on the one hand characterised the voice onset as being gradual or abrupt, and on the other hand could detect irregularities during the first phase of the voice onset in terms of amplitude and frequency changes.

It turned out that stutterers used an abrupt voice onset considerably more frequently in their fluent speech utterances than nonstutterers (72.8% vs. 54.4%). Furthermore, there was a clear tendency for irregularities in the amplitude level and/or the duration of the individual periods to occur more often in the EGG for stutterers than for nonstutterers, but these group differences were not significant. The differences between stutterers and nonstutterers in the Psg and EGG registration were not reflected in the acoustic measures. This can be explained by the fact that only the strictly perceptually fluent utterances were selected for the investigation. However, it is also conceivable that the discrepancy between the EGG and audio characteristics was the result of the use of different speech strategies by stutterers.

Irregularities in subglottal pressure build-up were found not to lead to irregularities during the onset of voicing. In other words, the respiratory manoeuvres, responsible for the subglottal pressure build-up, and the laryngeal manoeuvres which initiate and maintain voicing, are to a certain extent independent processes. These findings indicate that it is not sensible to draw conclusions from measurements at one level in the production of speech for another level.

The research described in **chapter eight** concerns itself with the question whether the frequently observed slower speech reaction times for stutterers result from problems in the preparation or programming of speech utterances or that they result from one or more peripheral disturbances during the onset of speech, summarised here under the leading of "problems in initiation". In a reaction time experiment the muscle activity of the neck and lips (EMG surface registration), the vocal cord activity (EGG) and the speech signal were registered simultaneously to this end for 20 stutterers and 20 nonstutterers.

The question mentioned above was approached in two ways. Firstly, the influence on the speech reaction time of two experimental variables, namely the length of a speech utterance (short words, long words and sentences) and the type or task (with and without preparation time) was investigated. Both experimental variables turned out to have a clear effect on the stuttering frequency. The percentage of disfluencies on the initial sound of an utterance turned out to be twice more large for longer words and sentences than for one-syllable words. Furthermore, the percentage of disfluencies in a task without preparation time was larger than in a task for which preparation of the utterance was possible.

The speech reaction times of stutterers' fluent speech utterances turned out to be considerably longer than the reaction times of the utterances of nonstutterers. This supports the data obtained in previous investigations in this field. The effect of the experimental variables on the speech reaction time was also very considerable. If stutterers had specific problems with the preparation or programming of the output, then for them the difference in reaction time between long and short utterances and the difference in reaction time between a task with and a task without preparation time would have to be longer than for nonstutterers. The results of this investigation support this hypothesis, although the effects that were found are not very large.

In a second approach the speech reaction time was subdivided into four intervals on the basis of physiological registrations. Subsequently it was checked whether the differences between stutterers and nonstutterers are greater in the early intervals, which could indicate problems in the programming of the speech utterance, or that these differences are greater in the later intervals, which could indicate problems with the initiation of the speech utterance. Stutterers turned out to be slower in the early as well as in the later intervals of the speech reaction time than nonstutterers. This indicates that both the preparation of speech utterances and the initiation of the speech movements themselves take more time for stutterers and therefore apparently give rise to problems. However, the differences between stutterers and nonstutterers turned out to be much slighter in the third and fourth intervals, which indicate that the greatest delay occurs for the first lip-movement and the first laryngeal activity.

No significant differences occurred between the subgroups in dividing the stutterers into groups of very mild, moderate and severe stutterers.

From the date pertaining to reaction time and stutter frequency it was found that stutterers experience most problems in initiating an utterance. These problems can be explained by a programming hypothesis, not only because the interval preceding the first manifestation of physiological activity is slowed down most for stutterers, but also because it is influenced most by the experimental variables. Furthermore, the data of this investigation support the explanation of stuttering as a disturbance in the peripheral motor processes. In the final paragraph of chapter eight both these models of explanation are discussed, as well as alternative explanations from the point of view of a hypothesis of attention, or from the viewpoint of acquired motor strategies. The final chapter ends with a number of proposals for further research.

The results of the experiments described in chapters three to eight allow the conclusion that the fluent speech of stutterers as compared with the speech of nonstutterers is characterised by a number of limitations. Firstly, for stutterers both the preparation of programming and the initiation of speech utterances takes more time than for nonstutterers. Secondly, during the initiation of speech movements stutterers regularly make use of types of subglottal pressure build-up not found with nonstutterers. Thirdly, for stutterers the voice onset in fluent speech utterances is more often abrupt than for nonstutterers. Fourthly, the timing of the respiratory and phonatory processes and/or the phonatory and articulatory processes seems to progress less precisely for stutterers than for nonstutterers.

In summary, it can be concluded that the mechanisms of speech which are responsible for the precise adjustment of the laryngeal musculature and for the smooth course of articulatory movements operate less precisely for stutterers than for nonstutterers. This limitation seems to be operative at different levels of speech motor control and performance.

The above conclusions are of interest for the diagnostics as well as for the therapy of stuttering. In diagnosing the complex problem of stuttering the speech motor processes which cannot be perceived must also be involved in the examination of stutterers. Information about the functioning of the speech motor system may determine, on the one hand, the choise of therapy and, on the other hand, the outline of a plan of therapy. For such an examination sufficient knowledge of the validity of the available battery of instruments is as yet lacking. If stuttering turns out to be the result, among other things, of limited speech motor capacities, it will then seem desirable to teach the stutterer motor skills which enable him to regulate and control his speech movements. In this way the direct acquisition of specific motor skills, with the help of which the stutterer will be able to regulate his rate of speech, and will be able to initiate the voice onset with more ease and a more relaxed way and which will also enable him to regulate the articulatory movements in a smoother way, will be more succesful than the use of other techniques such as the application of retarded auditive feedback of speech, the application of masked noise or the use of rhythm, all of which induce fluency indirectly.

Another issue concerns the use of therapy strategies in acquiring fluent speech. The effect of therapy strategies turns out to be dependent on the level in the production of speech at which a therapy strategy is aimed. This means that it cannot be expected that, for example, there will be a transfer of skills from articulatory training to the way voice onset takes place, or, vice versa, that changes in the way voice onset takes place directly influence the articulatory movements. This possibly explains why therapies aimed more specifically at certain levels of speech production yield such diverse results. In view of the wide distribution of individual stutterers in speech physiological research it may be hypothesized that stutterers are everything but a homogeneous group with respect to possible speech motor limitations.

In het verleden is stotteren dikwijls benaderd als een uitsluitend of primair emotioneel probleem. Terwijl aanvankelijk het uitgangspunt was dat stotteren als een neurose beschouwd diende te worden, kwam later onder invloed van psychologische leertheorieën het accent meer te liggen op direct aan het spreken gekoppelde spanningen of emoties die verstoringen in de vloeiendheid zouden uitlokken of veroorzaken. De laatste jaren is in de benadering van het stotterprobleem een geleidelijke verschuiving waarneembaar in de richting van de spraakmotorische aspecten van de stoornis. Dit proefschrift is een verzameling experimentele studies waarin deze verschuiving in de benadering van het stotterprobleem weerspiegeld wordt.

In het eerste deel van dit proefschrift (deel A) wordt de relatie tussen stotteren en angst nader bestudeerd. Het experimentele onderzoek hiernaar wordt ingeleid door het **eerste hoofdstuk** waarin eerst de meest invloedrijke benaderingen van stotteren in de afgelopen decennia geordend worden op basis van de plaats en functie die angst of spanning rond het spreken in de betreffende opvatting inneemt. Hierbij wordt een indeling gemaakt in (1) de benaderingen waarbij angst gezien wordt als voorafgaand aan stotteren en derhalve als stotteren uitlokkend, (2) de multifactoriële opvattingen waarbij angst beschouwd wordt als een relevante maar niet causale factor, en (3) de opvattingen waarbij angst in spreeksituaties gezien wordt als een directe consequentie van het stotteren. Vervolgens wordt het experimentele onderzoek naar verschillende aspecten van de relatie tussen stotteren en angst besproken. Dit onderzoek levert weinig evidentie op voor een directe aetiologische relatie tussen stotteren en angst. Het betreffende onderzoek heeft echter veel beperkingen en laat derhalve geen verreikende conclusies toe. Met name in een klinisch kader lijkt een multifactoriële benadering van het stotterprobleem een aantrekkelijk standpunt te vormen. Een dergelijke benadering geeft klinisch vooralsnog de meeste mogelijkheden om aan een veelheid van specifiek individuele aspecten van het stotterprobleem aandacht te besteden.

In het **tweede hoofdstuk** wordt een experiment beschreven waarin onderzocht wordt in hoeverre de anticipatie van spreeksituaties een verhoging van het spanningsniveau met zich meebrengt en daardoor spraakmotorische ontregelingen zou kunnen uitlokken. Hiertoe werden bij 24 stotteraars en

24 niet-stotteraars verschillen in subjectief ervaren spanning en fysiologische activiteit (electrodermale activiteit, vasomotorische reakties en hartslag) onderzocht vlak voor en tijdens de uitvoering van spreektaken (lezen en spontaan spreken) en niet-spreektaken (motorische taak en intelligentie taak). Verschillen tussen stotteraars en niet-stotteraars kwamen hoofdzakelijk naar voren in angst-ratings na afloop van een taak. Deze verschillen waren het grootst na de spreektaken en traden nauwelijks op na de andere taken. In meetwaarden van de fysiologische activiteit zowel voor als tijdens de uitvoering van spreektaken kwamen geen verschillen tussen stotteraars en niet-stotteraars naar voren. Wel bleken de meetwaarden in spreeksituaties hoger te zijn dan in niet-spreeksituaties, maar dit was voor beide groepen gelijkelijk het geval. Dit laatste duidt op de aanwezigheid van een meer algemene communicatieve stressfactor in spreeksituaties bij beide groepen. Bij nadere analyse van het verloop van het arousal-niveau gedurende de taken zelf bleek dat er bij niet-stotteraars tijdens de taakuitvoering een snellere afname optrad. Op grond van de resultaten van dit experiment kan worden geconcludeerd dat de verschillen tussen stotteraars en niet-stotteraars (als groep) met betrekking tot angst in spreeksituaties veel minder groot zijn dan dikwijls verondersteld wordt. Zo er al verschillen zijn dan manifesteren deze zich in de spreeksituatie zelf en niet gedurende de anticipatieperiode voorafgaand aan de spreekopdracht. Dit duidt erop dat spanning of angst in spreeksituaties eerder als een consequentie van het stotteren dan als een antecedente conditie beschouwd dient te worden.

Het ontbreken van significante verschillen tussen de groepen in de fysiologische activiteit (arousal-niveau) kan veroorzaakt zijn door grote individuele verschillen binnen de groep van stotterende proefpersonen. Vanuit een angsttheoretische benadering van het stotterprobleem ligt het voor de hand te verwachten dat een hoger arousal-niveau het sterkst aanwezig zal zijn bij ernstiger stotteraars. Teneinde de invloed van de stotterernst na te gaan, worden in het **derde hoofdstuk** de data van het in hoofdstuk twee beschreven experiment nader geanalyseerd voor verschillende niveaus van stotterernst. Hiertoe werd de groep stotteraars op basis van de stotterfrequentie tijdens de spreektaken in het onderzoek gesplitst in drie subgroepen: lichte, middelmatige en ernstige stotteraars. De gemiddelde meetniveaus voor de spontane fluctuaties in de electrodermale activiteit, de vasomotorische reacties en de hartslag verschilden noch in de anticipatie periode, noch in de taakuitvoering tussen de drie subgroepen. Met betrekking tot de electrodermale activiteit bleek het huidgeleidingsniveau echter wel een verschil op te leveren, met dien verstande dat de groep ernstige stotteraars een hoger huidgeleidingsniveau liet zien dan de groep middelmatige en lichte stotteraars, die op hun beurt niet verschilden van de niet-stotteraars. Deze tendens bleek echter ook in de niet-spreektaken aanwezig. Met betrekking tot het verloop van het arousal-niveau bleek dat bij het herhaald uitvoeren van eenzelfde taak er bij de subgroep ernstige stotteraars een snellere aanpassing optrad dan bij de beide andere subgroepen van stotteraars waarbij de afname van het arousal niveau hetzelfde verloopt als bij de niet-stotteraars. Binnen eenzelfde taak bleek het aanpassingsproces voor elk van de drie subgroepen van stotteraars echter hetzelfde te verlopen.

Ondanks het feit dat de verschillen in de arousal-meetwaarden tussen de drie subgroepen alleen optreden in de huidgeleidingsniveaus en ondanks het gegeven dat deze verschillen zeer gering en maar marginaal significant zijn, nuanceren de analyses van hoofdstuk drie de algemene conclusies van hoofdstuk twee. Deze conclusies lijken te gelden voor lichte en middelmatige stotteraars, maar mogelijk in mindere mate voor ernstigere stotteraars, die zowel tijdens de anticipatie van een taak als tijdens de uitvoering ervan een tendens naar een hoger arousal-niveau laten zien. Hiervoor worden aan het eind van hoofdstuk drie een aantal verklaringen gegeven. Hoofdstuk drie wordt afgesloten met een beschouwing zowel over de beperkingen van het beschreven onderzoek, als over de problemen bij het interpreteren van arousal-metingen, waardoor de onderzoeksdata geen generaliseringen toelaten. Enerzijds is de interpretatie van fysiologische angstmaten uitermate moeilijk, anderzijds wordt hiermee alleen de fysiologische component van het response complex "angst" gemeten. Voorts wordt in dit onderzoek de subjectieve ervaring van angst achteraf gemeten met behulp van een schaalmethode waarvan de betrouwbaarheid en validiteit discutabel is, terwijl ook geen aan angst of spanning gerelateerde gedragsveranderingen gemeten werden. De feitelijke relatie tussen stotteren en angst is nog allesbehalve duidelijk. Voor een benadering van het stotterprobleem als zijnde veroorzaakt door een algemene angstfactor, wordt in het beschreven onderzoek echter geen evidentie gevonden. Verder onderzoek naar de relatie tussen stotteren en angst is wenselijk, maar zeer gecompliceerd. Hoofdstuk drie wordt afgesloten met een bespreking van de experimenteel methodologische problemen bij het onderzoek naar het effect van spanning of angst op spraakgedrag.

Het tweede deel van dit proefschrift (deel B) richt zich op verschillende aspecten van de spraakmotoriek bij stotteraars. Het **vierde hoofdstuk** geeft een inleiding op de experimentele onderzoekingen die in de hoofdstukken vijf tot en met acht beschreven worden. Dat hoofdstuk beschrijft allereerst de motorische en fysiologische processen tijdens het spreken, alsmede de niveaus waarop deze gemeten kunnen worden. Daarna volgt een overzicht van recent spraakfysiologisch onderzoek bij stotteraars, gevolgd door een beschrijving van de belangrijkste opvattingen waarin stotteren primair als een stoornis in de spraakmotoriek opgevat wordt. Uit eerder spraakfysiologisch onderzoek blijkt dat er in vloeiende en niet-vloeiende spraakuitingen van stotteraars, zowel binnen de bij het spreken betrokken motorische subsystemen afzonderlijk - respiratie, fonatie en articulatie -, alsook in de coördinatie tussen deze subsystemen onderling, een aantal onregelmatigheden optreden die bij niet-stotteraars niet worden waargenomen. Met name bij het op gang komen van spraakbewegingen lijken zich verschillende afwijkingen voor te kunnen doen, zoals een verhoogde laryngeale spieractiviteit, een inadequate coördinatie van de intrinsieke larynxspieren, een inadequate timing van lip-, kaak- en tongbewegingen en een niet optimale coördinatie van respiratie, fonatie en articulatiebwegingen. Voorts blijkt het op gang komen van spraakbewegingen bij stotteraars trager te verlopen.

In de hoofdstukken vijf tot en met acht worden een aantal eigen studies beschreven waarin verschillende facetten van het op gang komen van spreekbewegingen nader onderzocht worden.

In het **vijfde hoofdstuk** wordt een onderzoek besproken waarbij de realisering van de steminzet wordt onderzocht op perceptueel en acoustisch niveau. Het gelijkmatig en geleidelijk op gang laten komen van de steminzet vorm in veel stotterbehandelingen een belangrijk onderdeel van de therapie. De evaluatie van de steminzet geschiedt in de klinische praktijk op basis van het auditieve oordeel. Over de betrouwbaarheid en de validiteit van dit oordeel is echter weinig bekend. In het onderzoek waarover in het vijfde hoofdstuk gerapporteerd wordt, werd allereerst de betrouwbaarheid van de auditieve oordelen van getrainde beoordelaars (logopedisten) over de abruptheid c.q. geleidelijkheid van de steminzet bepaald. Deze betrouwbaarheid blijkt redelijk te zijn, maar niet buitengewoon hoog (intra-class correlatie = .74 bij een extreem grote stimulus range). Vervolgens werd een zestal acoustische maten ontwikkeld voor de beschrijving van de amplitude omhullende van vocaal-consonant uitingen. Met behulp van correlatie en multipele regressie analyses werd vervolgens de bruikbaarheid van deze maten als voorspeller van de waargenomen steminzet onderzocht. Het blijkt dat de logarithme van de tijd die de amplitude nodig heeft om van 10% tot 90% van haar maximum niveau te komen, de krachtigste voorspeller is van de waargenomen abruptheid van de steminzet. Mits op de juiste manier geschaald, blijkt deze maat vergelijkbaar te zijn met een "typische" beoordelaar. De overige maten, die werden afgeleid van een benadering van de omhullende door opeenvolgende lijnstukken en de maximum amplitude die in de stimulus bereikt wordt, blijken in wezen dezelfde informatie te bevatten als de stijgingsmaat. Het onderzoek toont aan dat de log-stijgtijdsmaat een goed bruikbare predictor is van de waargenomen abruptheid van de steminzet en daardoor veelbelovende mogelijkheden biedt voor de constructie van een eenvoudig apparaat om de stem- of stottertherapeut te helpen bij het bepalen van de hardheid van de steminzet. Hoofdstuk vijf wordt afgesloten met de beschrijving van een schema voor het ontwerp van een dergelijk apparaat.

Het onderzoek dat in het **zesde hoofdstuk** beschreven wordt richt zich op de aerodynamische processen die een rol spelen bij het op gang komen van de fonatie. In dit onderzoek werd onderzocht hoe het subglottale drukniveau, nodig voor het op gang komen van de fonatie, opgebouwd wordt in vloeiende spraakuitingen van stotteraars en niet-stotteraars bij verschillende manieren van spreken. Volgens een aantal auteurs vormt het onvermogen om ademhalingsbewegingen op de juiste manier te coördineren met een globale instelling van het strottehoofd als voorbereiding op de fonatie, een belangrijke oorzaak van verstoringen in het vloeiend op gang komen van de fonatie. Systematisch onderzoek naar de coördinatie van uitademing en de instelling van het strottehoofd ontbreekt vooralsnog. In dit onderzoek konden met een hoge mate van betrouwbaarheid vijf verschillende typen van subglottale drukopbouw gedetecteerd worden. Aan deze typen kon tevens een duidelijke en inzichtelijke fysiologische verklaring gegeven worden. In normale spraak bleken stotteraars in perceptueel vloeiende uitingen significant vaker ongewone patronen van subglottale drukopbouw te gebruiken dan niet-stotteraars (26,6% versus 3,1%). Het voorkomen van afwijkende typen drukopbouw bleek niet gerelateerd te zijn aan de stotterernst.

In het onderzoek werd voorts het effect nagegaan van verschillende wijzen van spreken. Voorafgaand aan het onderzoek worden de proefpersonen in twee, in stottertherapieën frequent gebruikte, spreekstrategieën getraind. Dit betrof spreken met een zeer geleidelijke steminzet en spreken met een verminderde articulatorische inspanning. Het effect van deze experimentele spreekcondities bleek zeer verschillend te zijn; terwijl spreken met een geleidelijke steminzet de subglottale drukopbouw rechtstreeks beïnvloedt, bleek spreken met een verminderde articulatiedruk hier geen invloed op te hebben. Het effect op de frequentie van vóórkomen van de verschillende typen subglottale drukopbouw was bij beide groepen gelijk. Omdat ook de benodigde trainingstijd bij beide groepen gelijk was kan hieruit worden afgeleid dat het voor stotteraars niet moeilijker is om specifieke fonatorische of articulatorische manoeuvres uit te voeren dan voor niet-stotteraars.

In het **zevende hoofdstuk** worden de interacties tussen respiratie, fonatie en articulatie nader bestudeerd. De frequentie van de in hoofdstuk zes beschreven typen subglottale drukopbouw (Psg) werd hierbij gerelateerd aan karakteristieken van fonatie en articulatie. Hiervoor werden simultaan met de subglottale druk de stembandactiviteit zoals die zich in electroglottografische registraties (EGG) weerspiegelt en het audio signaal geregistreerd. Voor de signaalanalyse van het EGG werd een kwalificatiesysteem ontwikkeld waarmee enerzijds de steminzet als geleidelijk of abrupt gekarakteriseerd werd en anderzijds onregelmatigheden in de eerste fase van de stemgeving in termen van amplitude- en frequentiewisselingen gedetecteerd konden worden.

Stotteraars bleken in hun vloeiende spraakuitingen aanzienlijk frequenter een abrupte steminzet te gebruiken dan niet-stotteraars (72,8% versus 54,4%). Daarnaast was er een duidelijke tendens dat onregelmatigheden in het amplitude niveau en/of de duur van de afzonderlijke periodes in het EGG meer bij stotteraars dan bij niet-stotteraars voorkomen, maar deze groepsverschillen waren niet significant. De verschillen tussen de stotteraars en de niet-stotteraars in de Psg- en EGG- registraties bleken zich niet te weerspiegelen in de acoustische maten. Dit kan verklaard worden vanuit het feit dat alleen de strikt perceptueel vloeiende uitingen voor het onderzoek werden geselecteerd. Het is echter ook heel goed denkbaar dat de discrepantie tussen de EGG- en audio-karakteristieken het gevolg geweest is van het gebruik van andere spreekstrategieën door stotteraars.

Onregelmatigheden in subglottale drukopbouw blijken niet te leiden tot onregelmatigheden in het op gang komen van de stemgeving. Met andere woorden: de respiratoire manoeuvres, die zorgdragen voor de subglottale drukopbouw, en de laryngeal manoeuvres, die de stemgeving initiëren en op gang houden, zijn tot op bepaalde hoogte van elkaar onafhankelijke processen. Deze bevindingen geven aan dat het niet verantwoord is vanuit metingen op het ene niveau in de spraakproductie conclusies voor een ander niveau te trekken.

Het onderzoek dat in het **achtste hoofdstuk** wordt beschreven, richt zich op de vraag of de frequent waargenomen tragere spraakreactietijden bij stotteraars het gevolg zijn van problemen in de voorbereiding of programmering van spraakuitingen danwel dat zij het gevolg zijn van één of meerdere perifere stoornissen bij het op gang komen van de spraak, hier verder samengevat onder initiëringsproblematiek. In een reactietijd-experiment werden hiertoe simultaan de spieractiviteit van hals en lip (EMG oppervlakte registratie), de stembandactiviteit (EGG), en het spraaksignaal geregistreerd bij 20 stotteraars en 20 niet-stotteraars.

De genoemde vraag werd op twee manieren benaderd. Allereerst werd de invloed van twee experimentele variabelen, namelijk de lengte van een spraakuiting (korte woorden, lange woorden en zinnen) en het type taak (een taak met en een taak zonder voorbereidingstijd) op de spraakreactietijd nagegaan. De beide experimentele variabelen bleken een duidelijk effect op de stotterfrequentie te hebben. Het percentage niet-vloeiendheden op de initiaal klank van een uiting bleek bij langere woorden en zinnen twee keer zo groot te zijn als in de eenlettergrepige woorden. Voorts was het percentage stotters in een taak zonder voorbereidingstijd groter dan in een taak warin de spraakuiting voorbereid kon worden.

De spraakreactietijden van vloeiende spraakuitingen van stotteraars bleken aanzienlijk langer te zijn dan die van de uitingen van niet-stotteraars, hetgeen data van eerdere onderzoekingen op dit terrein bevestigt. Ook het effect van de experimentele variabelen op de spraakreactietijd was zeer groot. Indien stotteraars specifieke problemen zouden hebben met de outputvoorbereiding oftewel programmering, dan zou bij stotteraars het verschil in reactietijd tussen lange en korte uitingen en het verschil in reactietijd tussen een taak met en een taak zonder voorbereiding groter moeten zijn dan bij de niet-stotteraars. De resultaten van dit onderzoek ondersteunen deze hypothese, doch de gevonden effecten zijn niet erg groot.

In een tweede benadering werd de spraakreactietijd op basis van de fysiologische registraties opgedeeld in vier intervallen en werd vervolgens nagegaan of de verschillen tussen stotteraars en niet-stotteraars groter zijn in de eerste intervallen, hetgeen zou kunnen wijzen op problemen met de programmering van de spraakuiting, of dat deze verschillen groter zijn in de latere intervallen, hetgeen op problemen met de initiëring van de spraakuiting zou kunnen wijzen. Stotteraars bleken zowel in de eerste intervallen als in de latere intervallen van de spraakreactietijd trager te zijn dan de niet-stotteraars. Dit wijst erop dat zowel de voorbereiding van de spraakuitingen als het op gang brengen van de spraakbewegingen zelf bij stotteraars meer tijd vraagt en derhalve kennelijk problemen oplevert. Wel bleken de verschillen tussen stotteraars en niet-stotteraars veel kleiner te zijn in het derde en vierde interval, hetgeen erop wijst dat met name voor de eerste lipbeweging en de eerste laryngeale activiteit de grootste vertraging optreedt.

Bij een verdeling van de groep stotteraars in lichte, middelmatige en ernstige stotteraars, kwamen geen significante verschillen naar voren tussen deze subgroepen onderling.

Uit de date omtrent reactietijd en stotterfrequentie blijkt dat stotteraars de meeste problemen ondervinden bij het begin van een uiting. Deze problemen kunnen verklaard worden vanuit een programmeringshypothese, omdat het interval voorafgaaand aan de eerste manifestatie van fysiologische activiteit bij stotteraars niet alleen het meest vertraagd is maar ook door de experimentele variabelen het sterkst wordt beïnvloed. Daarnaast wordt echter ook een verklaring waarbij stotteren opgevat wordt als een stoornis in de perifere motorische processen, door de data van dit onderzoek ondersteund. In de laatste paragraaf van hoofdstuk acht worden zowel deze beide verklaringsmodellen, alsook alternatieve verklaringen vanuit een aandachtshypothese of vanuit aangeleerde motorische strategieën besproken. Het laatste hoofdstuk wordt afgesloten met een aantal voorstellen voor verder onderzoek.

De resultaten van de in hoofdstuk drie tot en met acht beschreven experimenten laten de conclusie toe dat de vloeiende spraak van stotteraars in vergelijking met de spraak van niet-stotteraars een aantal motorische beperkingen kent. Allereerst neemt zowel de voorbereiding of programmering als de initiëring van spraakuitingen bij stotteraars meer tijd in beslag dan bij niet-stotteraars. Ten tweede gebruiken stotteraars regelmatig tijdens de initiëring van spraakbewegingen typen subglottale drukopbouw welke bij niet-stotteraars niet worden waargenomen. Ten derde starten stotteraars in vloeiende spraakuitingen de stemgeving vaker met een abrupte steminzet dan niet-stotteraars. Ten vierde lijkt de timing van respiratie- en fonatieprocessen en/of fonatie- en articulatieprocessen bij stotteraars minder precies te verlopen dan bij niet-stotteraars.

Samenvattend kan geconcludeerd worden dat de spraakmechanismen die verantwoordelijk zijn voor de precieze instelling van de laryngeale musculatuur en voor het vloeiend verloop van articulatiebewegingen, bij stotteraars op een minder nauwkeurige manier opereren dan bij niet-stotteraars; deze beperking lijkt op verschillende niveaus van spraakmotorische controle en uitvoering aanwezig te zijn.

Bovenstaande conclusies zijn zowel voor de diagnostiek als voor de therapie stotteren van belang. Bij de diagnostiek van het complexe probleem dat stotteren is dienen ook de spraakmotorische processen die zich aan deze perceptuele waarneming onttrekken in het onderzoek van stotteraars betrokken te worden. Gegevens over het spraakmotorisch functioneren kunnen enerzijds de therapiekeuze en anderzijds de opstelling van een therapieplan mede bepalen. Voor dergelijk onderzoek ontbreekt het vooralsnog aan voldoende kennis met betrekking tot de validiteit van het voorhanden zijnde meetinstrumentarium.

Wanneer stottergedrag onder meer het gevolg blijkt te zijn van beperkte spraakmotorische capaciteiten, lijkt het gewenst de stotteraar motorische vaardigheden aan te leren waarmee hij in staat is zijn spraakbewegingen te reguleren en te sturen. Hierbij zal het direct aanleren van specifieke motorische vaardigheden, waarmee de stotteraar zijn spreektempo kan reguleren, zijn stemgeving gemakkelijker en meer ontspannen op gang kan brengen en de articulatiebwegingen vloeiender kan laten verlopen, succesvoller kunnen zijn dan het gebruik van technieken als toepassen van vertraagde auditieve terugkoppeling van spraak, maskerende ruis of gebruik van ritme, waarmee vloeiendheid indirect geinduceerd wordt.

Een en ander aspect betreft het gebruik van therapiestrategieën bij het aanleren van vloeiende spraak. Het effect van therapiestragieën blijkt afhankelijk te zijn van het niveau in de spraakproductie waarop een bepaalde therapiestragie zich richt. Dit houdt in dat niet verwacht mag worden dat er bijvoorbeeld van een articulatietraining een overdracht naar de manier van stemgeving uitgaat, of omgekeerd dat veranderingen in de stemgeving een directe invloed hebben op de articulatiebewegingen. Dit laatste verklaart mogelijk ook waarom therapieën die zich meer specifiek op een bepaald niveau van de spraakproductie richten zulke uiteenlopende resultaten kunnen geven bij verschillende stotteraars. Gezien de grote spreidingen tussen individuele stotteraars in de spraakfysiologische experimenten kan namelijk worden verondersteld dat stotteraars met betrekking tot hun eventuele spraakmotorische beperkingen alles behalve een homogene groep vormen.

Het in dit proefschrift beschreven onderzoek zou niet mogelijk geweest zijn zonder de intensieve samenwerking met de vakgroep Functieleer van het Psychologisch Laboratorium speciaal met dr. W. Hulstijn en met het Instituut Fonetiek in de persoon van dr. L. Boves; de infrastructurele voorzieningen die vanuit deze samenwerking gegroeid zijn vormen nu een vruchtbare basis voor de verdere uitbouw van een onderzoeksprogramma op het gebied van spraakpathologie.

Bij de uitvoering van de verschillende experimenten en bij de signaalverwerking was de onderzoeksassistentie van Maarten Cox, Ineke van Dielen en Elly Cloudt onmisbaar: hun hulp en inzet heb ik op hoge prijs gesteld. Ruud Meulenbroek leverde een waardevolle bijdrage in de ontwikkeling van de programmatuur voor de EMG-signaal analyse. Ron Friessen en Erik-Jan de Rijk droegen tijdens hun wetenschappelijke stage bij in de ontwikkeling van de scoringssystemen voor resp. de subglottale drukmetingen en de electroglottografische registraties.

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Prof. C.W. Starkweather, ph.d. (Temple University, Philadelphia, U.S.A.) en Prof. R.L. Webster, ph.d. (Hollins College, Roanoke, U.S.A.) gaven kritisch commentaar bij eerdere versies van verschillende hoofdstukken; Woody Starkweather bood daarnaast belangrijke redactionele hulp. Judith Abma-Hill en Bas Aarts droegen zorg voor de vertaling van de inleiding en samenvatting.

Een groot beroep heb ik gedaan op Diny Helsper die slagvaardig en met veel precisie de verschillende artikelen heeft getypt en met veel zorg het uiteindelijke manuscript drukklaar maakte. Op Caren van de Berk, Ineke Rijnbout-Kuiper en Anja Meij kon ik altijd een beroep doen wanneer ad hoc assistentie nodig was.

Veel waardering heb ik voor de wijze waarop de medewerkers van de afdeling Stem- en Spraakstoornissen in de werksituatie rekening hielden met het uitvoeren van de experimenten en de beperking van mijn aandacht voor het afdelingsgebeuren tijdens de afronding van dit proefschrift accepteerden.

Aan allen die op hun eigen wijze medewerkten aan het onderzoek en het tot stand komen van dit proefschrift: mijn hartelijke dank.

Herman F.M. Peters werd op 2 december 1938 in Nijmegen geboren. In 1958 behaalde hij het diploma HBS-A aan het Canisius College in deze stad. Hierna vervulde hij zijn dienstplicht als aspirant reserve-officier bij de Koninklijke Landmacht. In 1960 begon hij zijn studie in de psychologie aan de Katholieke Universiteit te Nijmegen, waar hij in 1967 het doctoraal examen aflegde met als hoofdrichtingen ontwikkelingspsychologie en klinische psychologie.

In 1967 werd hij benoemd tot wetenschappelijk medewerker bij het Medisch Psychologisch Instituut (toenmalig hoofd: Prof.Dr. P.J.A. Calon) en van daaruit gedetacheerd bij de afdeling Stem- en Spraakstoornissen van de Kliniek voor Keel-, Neus- en Oorziekten (toenmalig: hoofd Prof. Dr. W.F.B. Brinkman). Sinds 1970 is hij ingeschreven in het Register van Klinisch Psychologen van het Nederlands Instituut van Psychologen. Hierna volgde een specialisatie op het gebied van de spraakpathologie, waarbinnen aanvankelijk spraak- en taalontwikkelingsstoornissen en later stotteren een speciaal aandachtsveld vormden.

Op de afdeling Stem- en Spraakstoornissen heeft hij naast klinische werkzaamheden de zorg voor de organisatie van onderwijs en onderzoek. Hij is belast met de opzet en organisatie van het onderwijsprogramma spraakpathologie dat vanuit de medische faculteit ten behoeve van de vrije studierichting Spraak- en Taalpathologie binnen de faculteit der letteren verzorgd wordt. Voorts is hij projectleider van verschillende onderzoeksprojecten op het gebied van spraakmotorisch onderzoek bij stotteren.

Hij is getrouwd met Hanneke Breuring en heeft twee zoons, Wimold en Harm.

STELLINGEN

I

In de klinische praktijk kunnen de objectiviteit en overdraagbaarheid van oordelen over stemkarakteristieken met relatief eenvoudig uit te voeren geautomatiseerde akoestische analyses aanzienlijk vergroot worden.

(dit proefschrift)

II

Bij stotteraars zijn spraakuitingen die auditief en visueel als vloeiend beoordeeld worden dikwijls niet vloeiend in spraakmotorische processen die zich aan de directe waarneming onttrekken.

(dit proefschrift)

III

Bij het spreken zijn respiratie, fonatie en articulatie relatief onafhankelijke processen. Vanuit de kennis omtrent het functioneren van het ene systeem mogen derhalve geen voorspellingen gedaan worden omtrent het functioneren van een van beide andere systemen.

(dit proefschrift)

IV

De uitbreiding van de diagnostiek bij stotteraars met instrumenteel onderzoek naar de coördinatie en timing van de verschillende spraakmotorische processen kan een belangrijke bijdrage leveren aan de indicatiestelling voor stottertherapie.

(dit proefschrift)

V

Wanneer bij de behandeling van stotteraars het verwerven van vloeiende spraak als therapiedoel gekozen wordt, verdienen therapiestrategieën waarbij de stotteraar zelf leert de spreekbewegingen te reguleren en te sturen de voorkeur boven indirecte technieken die vloeiendheid induceren.

VI

Het uiteindelijke resultaat van een op spraakverandering gerichte stottertherapie is in sterke mate afhankelijk van de individuele kosten-baten analyse door de betrokken stotteraar, t.w. enerzijds de inspanning die nodig is voor het verwerven en in stand houden van vloeiende spraak en anderzijds het nuttig effect hiervan in zijn dagelijks leven.

VII

Een ruimere plaats voor geintegreerd onderwijs in de vakken die in de V.S. samengevat worden onder de term "speech science" binnen de opleiding logopedie, zal de vakinhoudelijke communicatie tussen logopedist en betrokken wetenschappelijke disciplines vergemakkelijken en voor de logopedist de toegang tot relevante vakwetenschappelijke literatuur verruimen.

VIII

De recentelijk gestarte vrije studierichting Spraak- en Taalpathologie aan de K.U.N. zal in de toekomst kunnen voorzien in de behoefte aan kader dat zorg draagt voor de noodzakelijke innovaties op het gebied van spraak- en taalpathologie, alsmede voor de implementatie van verworvenheden uit ondersteunende vakgebieden.

IX

Een doorstroming van afgestudeerden van de vrije studierichting Spraak- en Taalpathologie naar de opleiding Logopedie voor een aangepaste tweede fase beroepsopleiding en omgekeerd van afgestudeerden van de opleiding Logopedie naar de universitaire opleiding zonder de belemmerende drempel van een universitair propedeutisch examen, zal ontwikkelingen op het gebied van de stem-, spraak- en taalpathologie ten goede komen.

X

Het zou wenselijk zijn als men binnen de logopedie een herkenbare specialisatie van logopedist-stemtherapeut, logopedist-taaltherapeut en logopedist-stottertherapeut zou nastreven in de vorm van daarop afgestemde voortgezette opleidingsprogramma's en registratie bij de voltooiing hiervan.

XI

De stichting van niet-universitaire centra voor stem-, spraak- en taalstoornissen waar geintegreerd multidisciplinair onderzoek en behandeling door foniater, spraakpatholoog, logopedist en psycholoog of pedagoog kan plaatsvinden zal een adequate doorverwijzing mogelijk maken vanuit de eerstelijns-gezondheidszorg en vanuit de inmiddels in het leven geroepen regionale V.T.O.-teams.

XII

De sociale implicaties van bezuinigingen binnen universitaire vakgroepen en diensten worden vaak ernstig onderschat.

XIII

De huidige trend om culturele manifestaties te laten sponseren door het bedrijfsleven zal leiden tot een ongewenste beperking van de artistieke vrijheid binnen de museum-, concert- en theaterwereld.

XIV

De opvatting dat de "Nouvelle Cuisine" een kookstijl is die te weinig geeft voor te veel geld doet onrecht aan haar kwalitatieve pijlers t.w. creativiteit en veranderde kookprincipes.

Stellingen behorende bij het proefschrift van Herman F.M. Peters:
STUTTERING: studies in speech motor behavior.

Nijmegen, 24 juni 1987